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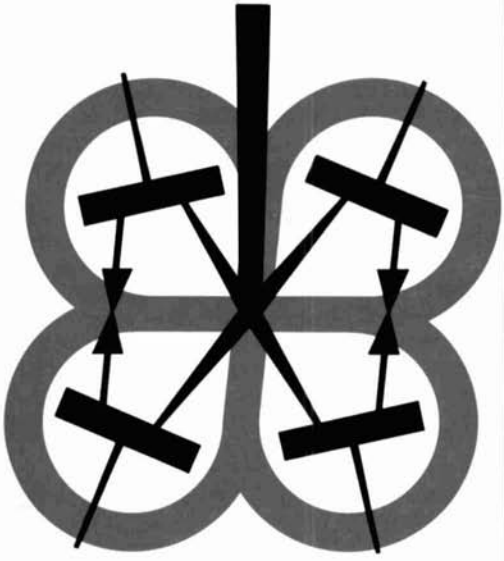
# ham radio magazine

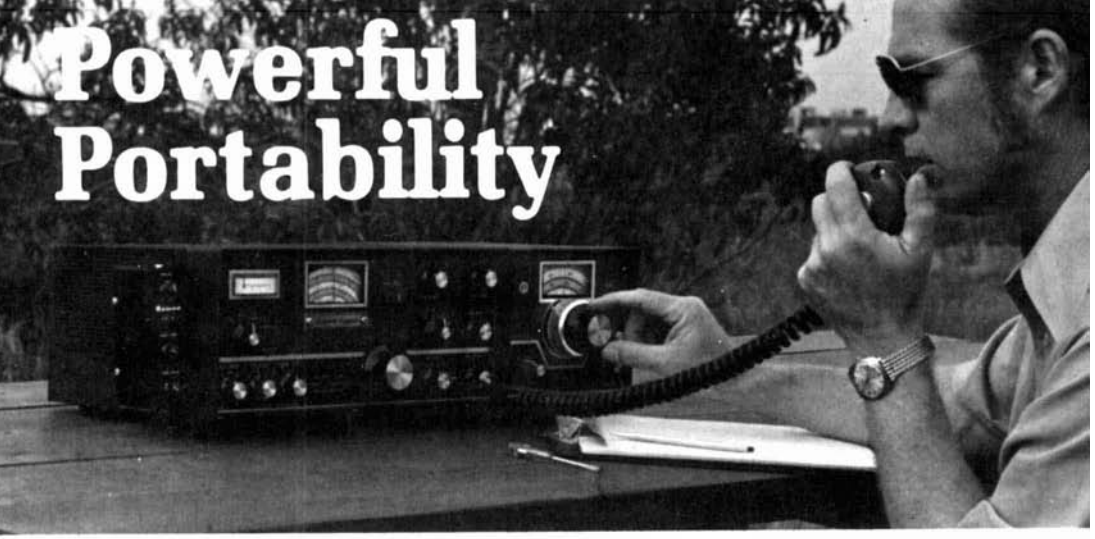
AUGUST 1974

# high-power solid-state LINEAR POWER AMPLIFIER



## this month


- wind loading on antenna structures 16
- vhf fm scanners 28
- ssb transceiver 34
- variable-speed RTTY 50

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More Details? CHECK–OFF Page 94

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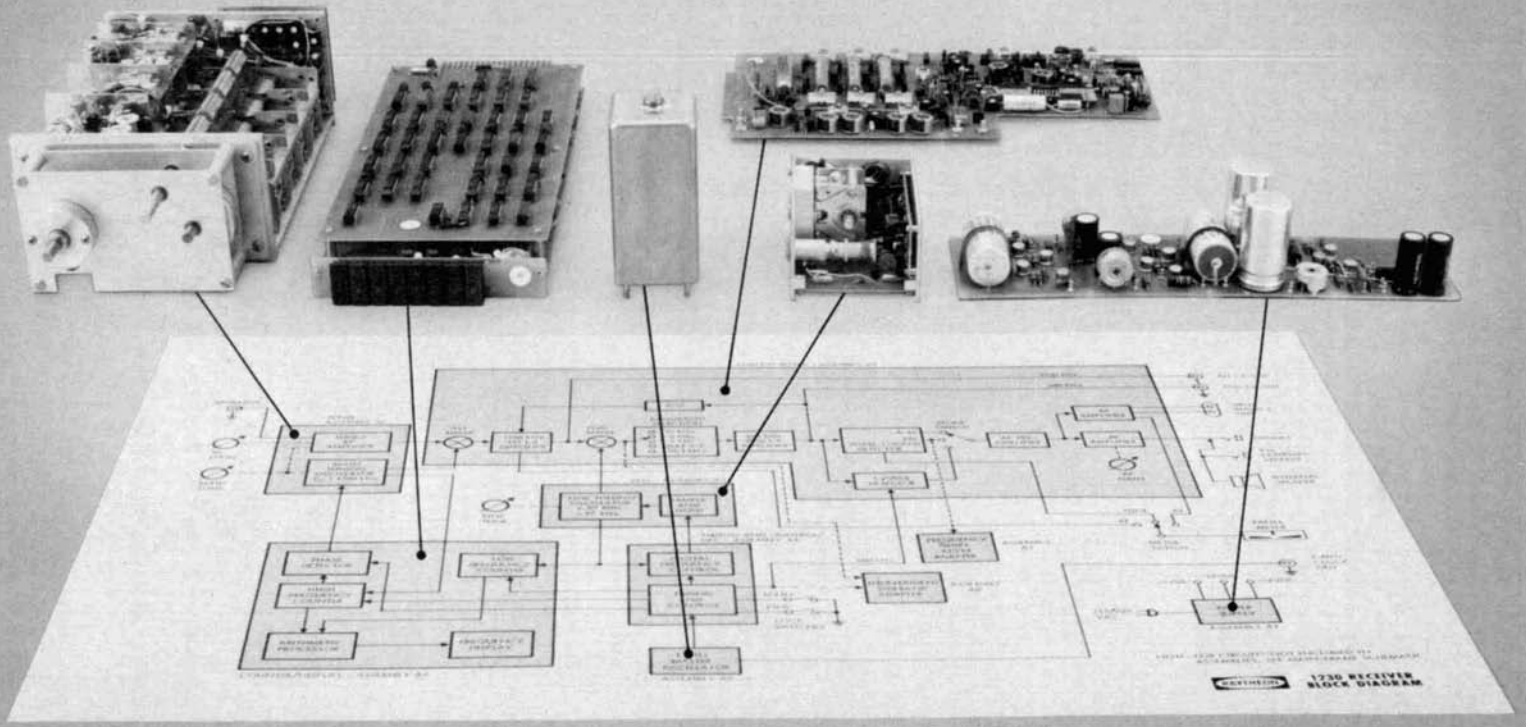


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# contents

**6 high-power linear power amplifier**
W. Steven Chambers

**16 wind loading on antenna structures**
John J. Nagle, K4KJ

**28 vhf fm scanners**
Joseph J. Carr, K4IPV

**34 IC ssb transceiver**
Brian D. Comer, G3ZCV

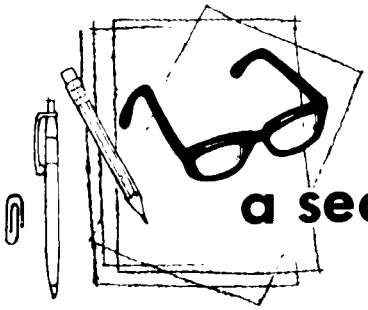
**40 harmonic phase detector**
Henry S. Keen, W5TRS

**44 shipboard amateur radio installations**
Robert P. Haviland, W3MR

**50 variable-speed RTTY control**
Keith H. Sueker, W3VF

**56 battery power**
Edward M. Noll, W3FQJ

**4 a second look**
**94 advertisers index**
**56 circuits and techniques**
**83 flea market**
**62 ham notebook**
**64 new products**
**94 reader service**



# a second look

by jim fisk

**In case you haven't noticed,** solid-state technology has finally caught up to the vacuum tube. A good example of modern semiconductors at work is illustrated in the high-power linear amplifier featured in this issue. Modern transistors also provide good gain and low noise well into the microwave region, and microwave power devices are now available. If you think the prices are still too high, forget for a moment those 2C39s, 2K25s and other exotic hardware you bought for peanuts on the surplus market. Compared with the decade-old *list* price of vacuum tubes that would do the same job, modern high-performance semiconductors are a best buy.

While millions of research hours (and dollars) have been spent in the pursuit of higher gain, lower noise and higher power rf and microwave devices, even more has been spent in the field of digital logic. First it was the low-frequency RTL logic family that got all the attention, then DTL, TTL, Schottky TTL, ECL and cmos -- each family offering more speed or less power consumption than the last. Now IBM researchers have developed a silicon structure that creates a vacuum-tube triode in silicon. Well, not exactly -- but the new device has the same space-charge-limited current flow that occurs between the cathode and the plate in a vacuum tube. The value of this achievement is that it is now possible to build very low-power logic that operates in the 10- to 100-MHz region.

This new logic, which is called SCL (for space-charge-limited), outperforms all other logic, power-wise, at switching rates over 1 MHz. Cmos circuits, while low-power kings at the lower frequencies, require more power than SCL devices at frequencies above 1 MHz. There is also a good possibility that these new SCL devices will be very attractive for low-level linear amplifiers. When operated at starved collector current levels of less than one microampere, SCL devices have shown current gains as high as 100,000. Furthermore, SCL devices theoretically should have all the low-noise performance of vacuum tubes because they have the same built-in noise cancellation that comes with space-charge-limited current flow. SCL semiconductors, of course, will be free of the heater noise that makes building low-noise vacuum tubes such a problem.

In an SCL device the space-charge-limited current flow takes place in the silicon substrate *under* a conventional lateral transistor which is located on the surface of the chip. The emitter, base and collector, in addition to providing connections to the device, provide the biases which form the operating fields that turn the n-type substrate into an SCL. The positive bias between the surface emitter and collector provide the cathode-plate potential (although only a fraction of a volt as compared to hundreds of volts in a vacuum tube, the principle is the same). The bias on the surface base creates a grid that controls the current between the cathode and plate. When the base is unbiased, a deep depletion region extends down into the silicon chip, virtually cutting off current flow. When the base is forward biased, the depletion region shrinks, allowing current to flow. The surface transistor, while notoriously slow, is never biased completely on, so it does not affect the speed of the SCL.

**Jim Fisk, W1DTY**
**editor-in-chief**

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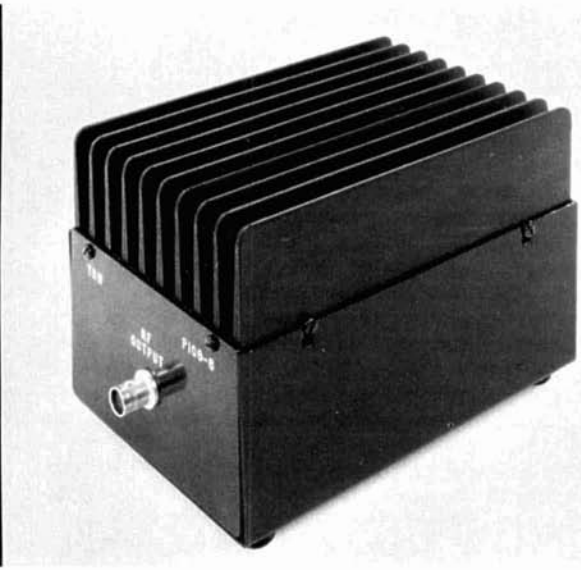


# high-power solid-state linear power amplifier

Complete construction details for a broadband linear with 320 watts output — including details on combining four basic amplifiers to build a solid-state kilowatt

Steve Chambers, Applications Engineer, TRW

**Chances are, when you** think of building a high-power, high-frequency linear rf power amplifier, you immediately think of using vacuum tubes. There has long been a need for high powered, solid-state rf amplifiers that offer highly reliable broadband operation, reducing the need for regular preventative maintenance. However, the achievement of such solid-state linear power amplifier (LPA) designs has been inhibited by the limitations of available transistors. Until recently they had low output power levels, required elaborate temperature compensation schemes and required precise power output control during conditions of high load vswr.

Several months ago, however, TRW Semiconductors introduced a new transistor developed for linear high-frequency ssb operation that is tolerant of mismatch, overdrive and wide temperature variations. This device is the TRW PT6665A/PT5788, rated at 100 watts,

either peak envelope power or CW. The PT6665A is in a flange-mounted package while the PT5788 is the stud-mounted version. These devices, in small quantities, cost about $36.00 each. When you consider the simplicity of the design and the lack of expensive high-voltage components (and a high-voltage power supply), this is quite reasonable. However, you do have to provide a rather husky 28-volt dc supply.

This article shows how to build a 320-watt (output) linear power amplifier using four TRW PT6665As in a two push-pull pair configuration. The broadband amplifier operates directly from a 28-volt dc source and covers the frequency range from 1.5 to 30 MHz without tuning. Four of these basic power amplifiers can be combined through summing networks, as will be discussed later, to build a conservative 1000-watt linear. Although it is possible to obtain 1000-watts *output* with only three of the basic amplifiers, IMD performance is reduced slightly, particularly at the upper power levels.

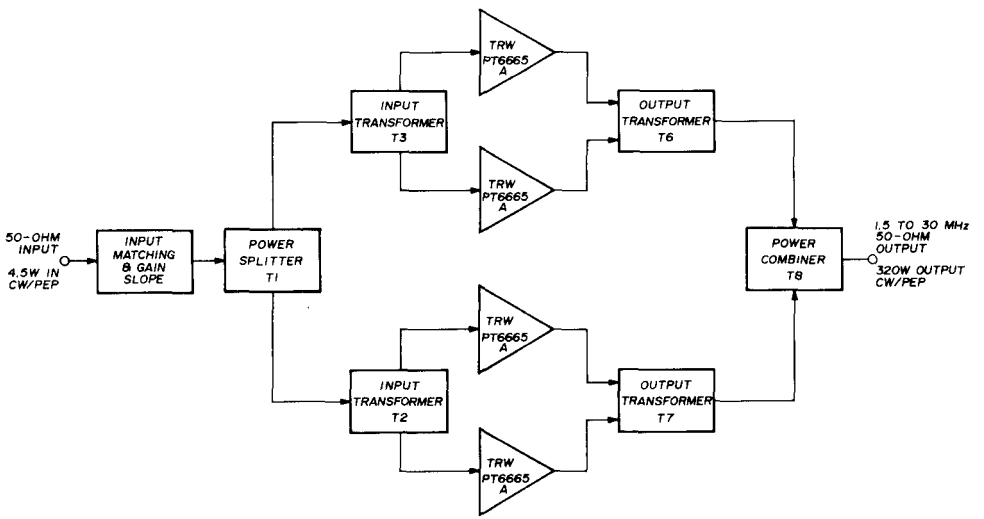



**fig. 1. Block diagram for the broadband solid-state 320-watt rf power amplifier that covers the frequency range from 1.5 to 30 MHz.**

The 320-watt linear amplifier shown in block form in **fig. 1** has a power gain of about 17 dB. As can be seen from **fig. 2**, 4.5 watts of drive power is all that is required for full power output at 30 MHz; less than two watts of drive is required for full rated output on 160 meters. This amplifier is capable of withstanding open- and short-circuit load conditions at full power output and the intermodulation distortion (IMD) is better than -32 dB. If power output is held to 250 watts, the IMD performance is better than -35 dB as plotted in **fig. 3.*** This is better than many vacuum

*IMD referenced to either of two equal tones as is standard amateur practice. IMD must be increased 6 dB for reference to peak power, or increased 3 dB for average power reference.

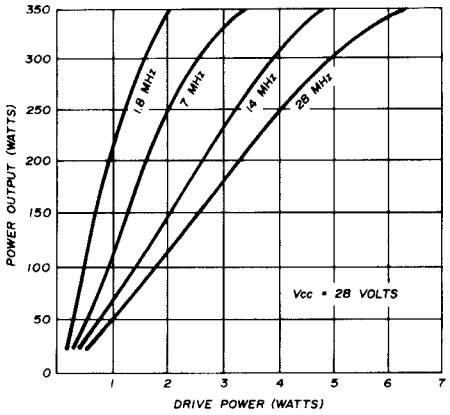



fig. 2. Drive requirements for the 320-watt power amplifier.

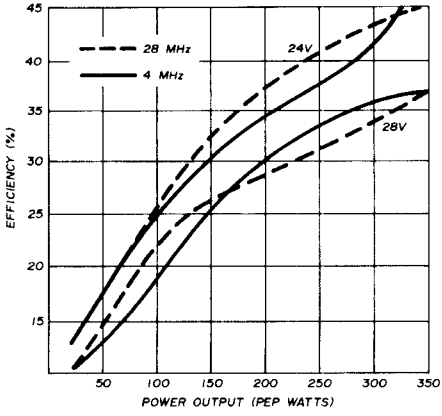



fig. 5. Gain and efficiency of the 320-watt linear amplifier vs supply voltage.

tubes, particularly the TV sweep tubes that are often used in amateur service at this power level. The affect of quiescent (idling) collector current upon IMD is shown graphically in **fig. 4**. Gain and efficiency of the amplifier are shown in **fig. 5**.

## circuit

Since class-B or -AB linear amplifiers are linear only with regard to their power-transfer characteristics, the output signal contains harmonics that are a function of the ratio of the cutoff frequency to the operating frequency and to the selectivity of the output matching network. This indicates that the power transistors be operated push-pull. With this arrangement, 40-dB rejection of the even-order harmonics is readily achieved, and the odd-order harmonics can be easily filtered. To achieve the goal of 320 watts *output* in this amplifier, two pairs of TRW PT6665A transistors are operated in push-pull and their outputs are combined in a zero-degree hybrid transformer (T8) as shown in **fig. 6**.

The input drive to the amplifier is divided equally between the two push-pull stages by the power splitter, T1, another zero-degree hybrid transformer. These transformers convert the 50-ohm source and load impedances into two 100-ohm parts which are in phase. Any

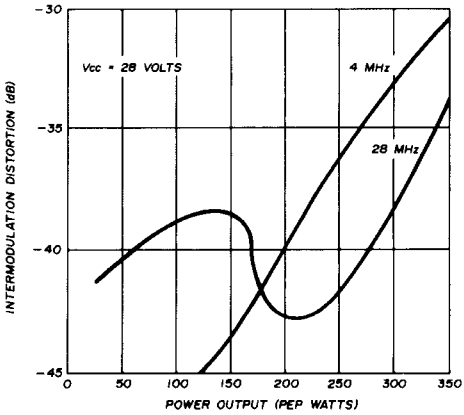



fig. 3. Intermodulation distortion of the solid-state linear amplifier at various power levels.

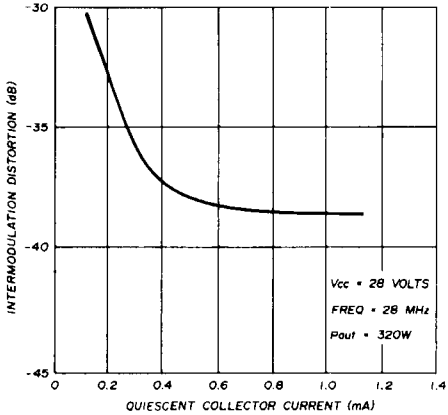



fig. 4. Affect of quiescent (idling) collector current upon intermodulation distortion.

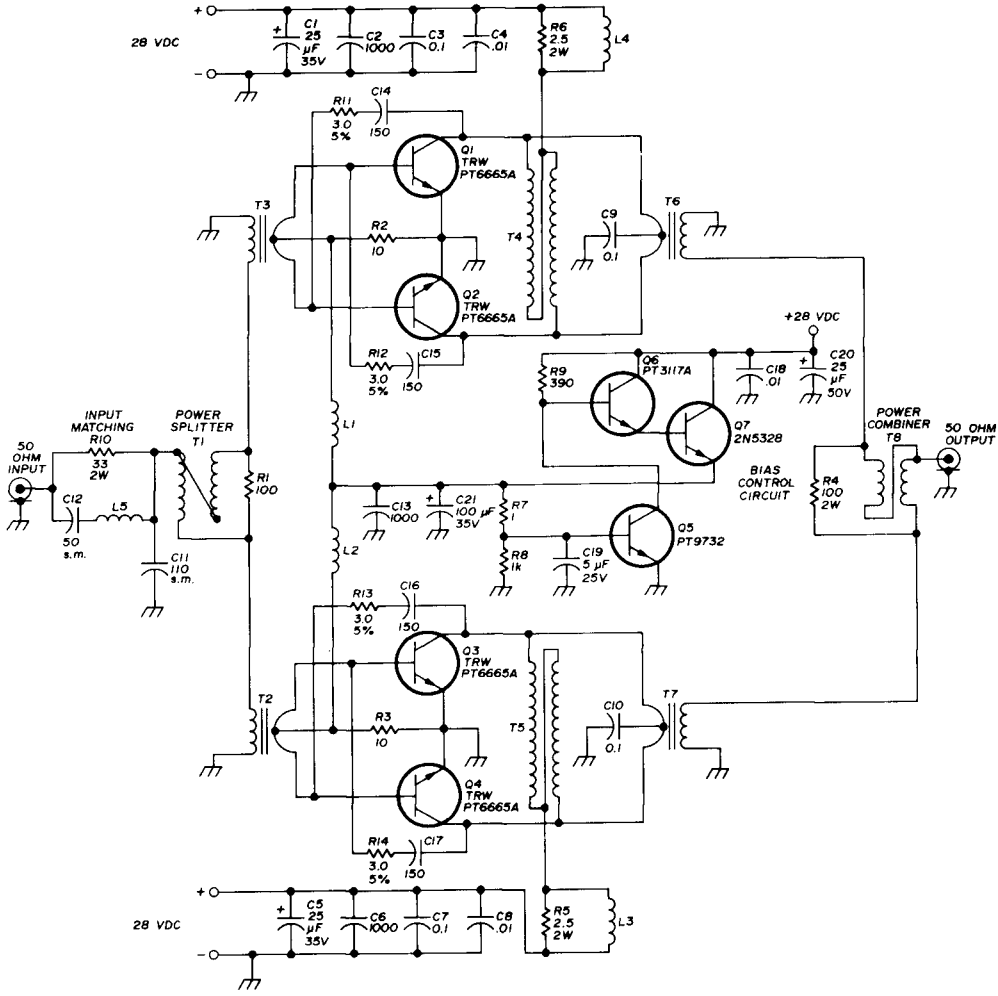
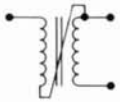



**fig. 6. Schematic diagram of the solid-state 320-watt linear power amplifier. Complete construction details for the transformers are shown in figs. 7 and 8. All resistors are ½-watt unless otherwise noted.**

amplitude or phase unbalance causes power to be dumped into resistors R1 and R4. The input impedance of the amplifier is near 50 ohms on 160 through 15 meters, going up slightly, to 75 ohms, on 10 meters:

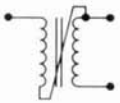
| | |
|---|---|
| 1.8 MHz | 50 + j3.5 ohms |
| 3.5 MHz | 49 + j1.0 ohms |
| 7.0 MHz | 48 + j1.3 ohms |
| 14.0 MHz | 49 + j3.2 ohms |
| 21.0 MHz | 55 + j10 ohms |
| 28.0 MHz | 70 + j2.5 ohms |
| 30.0 MHz | 75 + j0 ohms |

| | |
|---|---|
| C1, C5 | 25-µF, 35-volt electrolytic |
| C2, C6 C13 | 1000 pF metal clad (Underwood Electric type J-101) |
| C14, C15 C16, C17 | 150-pF metal clad (Underwood Electric type J-101) |
| C19 | 5-µF, 25-volt electrolytic |
| C20 | 25-µF, 50-volt electrolytic |
| C21 | 100-µF, 35-volt electrolytic |
| L1, L2 L3, L4 | 5 turns no. 20 enameled on one Fair-Rite CN20 ferrite bead (available from Amidon Associates) |
| L5 | 0.56-µH molded inductor |
| Q1, Q2 Q3, Q4 | TRW type PT6665A |
| Q5 | TRW PT9732 (thermally connected to heatsink) |
| Q6 | TRW PT3117A (200 mA transistor) |
| Q7 | TRW 2N5328 (2 amp transistor) |
| R5, R6 | 2.5 ohms (four 10-ohm, ½-watt resistors in parallel) |



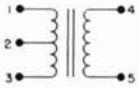
T1

Twisted pair no. 18 wire, 5 twists per inch (not critical), wound through two rows of CN-20 ferrite beads, 3 beads per row.



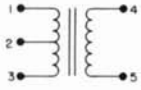
T4, T5, T8

Twisted pair no. 18 wire, 5 twists per inch (not critical), wound through two rows of CN-20 ferrite beads, 12 beads per row.




T2, T3

Terminals 1 and 3: One turn consisting of two pieces brass tubing, 0.190" (5 mm) OD, 8.80" (20 mm) long, each piece of tubing threaded through 3 CN-20 ferrite beads. Terminals 4 and 5: 3 turns no. 18 enamelled wire, wound through centers of brass tubing.

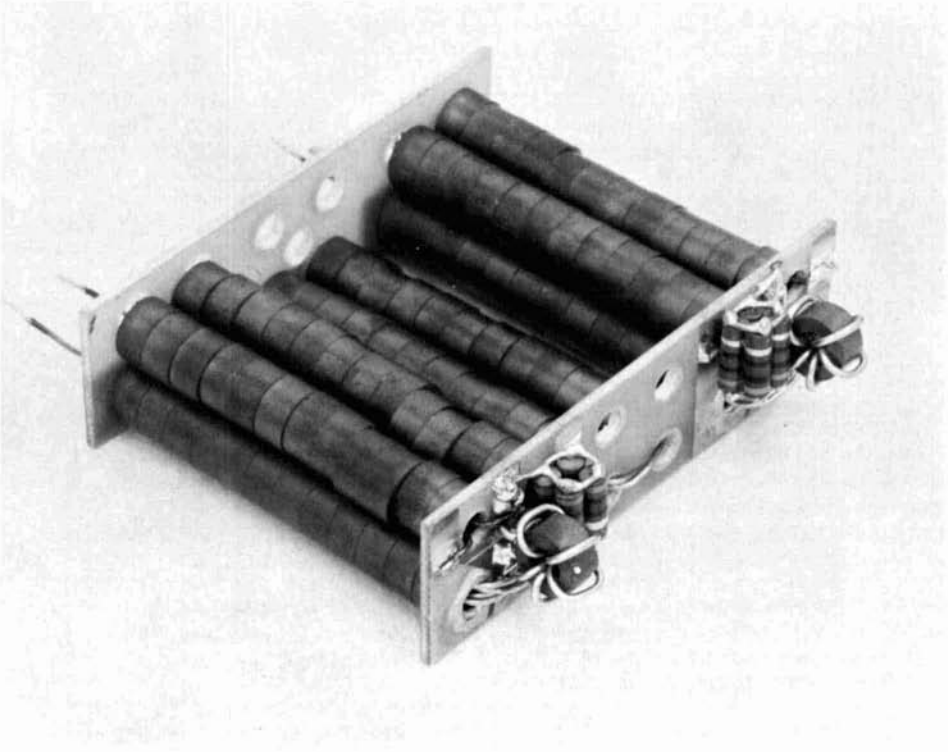



T6, T7

Terminals 2 and 3: One turn consisting of two pieces brass tubing, 0.190" (5 mm) OD, 2.50" (64 mm) long, each piece of tubing threaded through 12 CN-20 ferrite beads. Terminals 4 and 5: 4 turns no. 18 enamelled wire, wound through centers of brass tubing.

**fig. 7. Winding details for transformers T1 through T8. All ferrite beads are Fair-Rite type CN-20 (No. 2643002401), length = 0.190" (5 mm), OD = 0.380" (10 mm), ID = 0.190" (5 mm). The completed transformer assembly is shown in fig. 8. The CN-20 beads are available from Amidon Associates, 12033 Otsego Street, North Hollywood, California 91607; 144 beads, $13.00.**

**fig. 8. Construction of the combiner transformers T4, T5, T6, T7 and T8. Transformer T8 is wound through two rows of ferrite beads in center; T5 is wound through two rows of beads and is mounted above T7 (left), transformer T4 is mounted above T6 (right). Complete winding details are given in fig. 7. Inductors L4 and L5 are to the right next to resistors R5 and R6 (see fig. 11).**



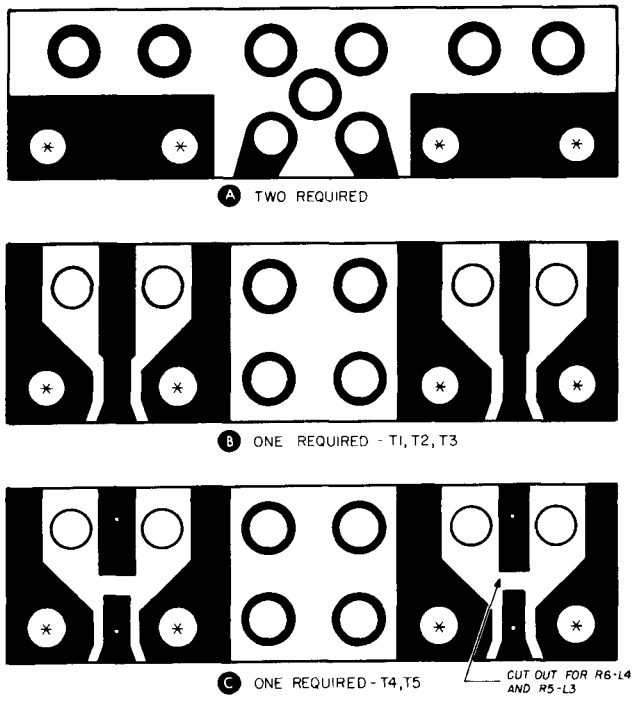



**fig. 9. Printed-circuit board for the combiner transformers uses single copper-clad board. Two pairs of boards are required for the amplifier. The 0.190" (5 mm) OD brass tubing is soldered in the holes marked with an asterisk.**

Transformers T2, T3, T6 and T7 each employ two ferrite-loaded brass tubes which form a center-tapped, U-shaped winding. The high-impedance winding is threaded, in continuous turns, through the brass tubing until the desired turns ratio is achieved. Winding and construction details for these transformers are shown in **fig. 7** and **8**.

The required turns ratio for the input transformer, T1, is determined by:

$$\frac{N1}{N2} = \sqrt{\frac{Z_{in}}{Z_{nom}}}$$

where $Z_{in}$ = summing port impedance (100 ohms)

$$Z_{nom} = \sqrt{Z_{LF}\, Z_{HF}}$$

The quantities $Z_{LF}$ and $Z_{HF}$ are the complex input impedance of the transistors at the low- and high-frequency extremes, respectively. For the TRW *PT6665A/PT5788, these values are:*

1.5 MHz: $Z_{LF} = 8.1 - j8 \cong |11.38|$ ohms
30 MHz: $Z_{HF} = 2.0 + j2 \cong |\ 2.83|$ ohms

Therefore, $Z_{nom}$ = 5.67 ohms and the required turns ratio for the input transformer is:

$$\frac{N1}{N2} = \sqrt{\frac{100}{5.67}} = 4.2$$

The turns ratio for the collector transformer is determined by the following equation:

$$\frac{N1}{N2} = \sqrt{\frac{Z_L\, P_o}{2(V_{cc} - V_{sat})^2}}$$

where: $Z_L$ = summing port impedance (100 ohms)
$P_o$ = combined output power for the pair of transistors (200 watts)
$V_{cc}$ = collector supply voltage (28 volts)
$V_{sat}$ = rf saturation voltage (1.5 volts)

For this amplifier,

$$\frac{N1'}{N2'} = \sqrt{\frac{100 \times 200}{2(28 - 1.5)^2}} = 3.8$$

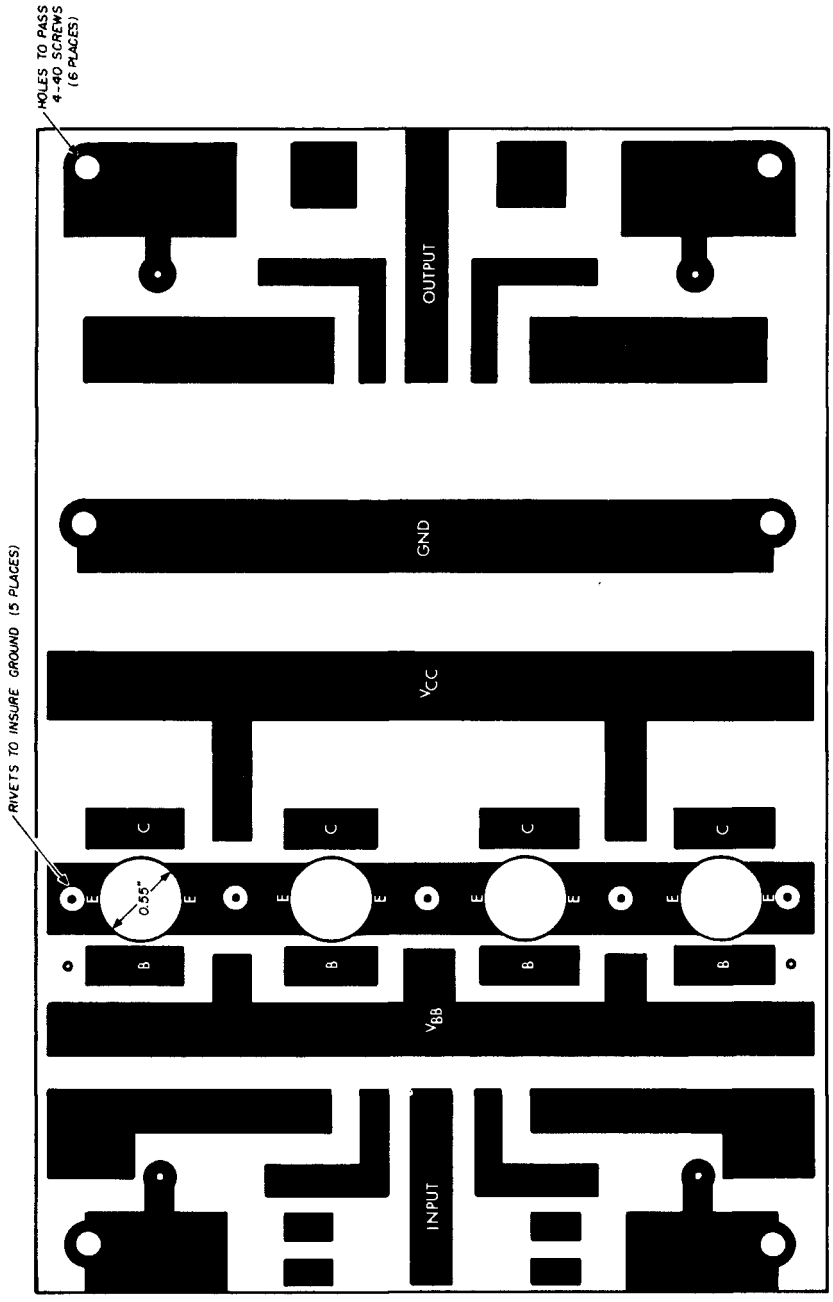



**fig. 10. Full-size printed-circuit layout for the 320-watt power amplifier. Parts placement is shown in figs. 11 and 12.**

The output transformer chosen for the amplifier uses the calculated turns ratio. However, for the input transformer a 3:1 ratio was used in place of the calculated 4.2:1 because it improves the match at 28 MHz. The gain-vs-frequency response and

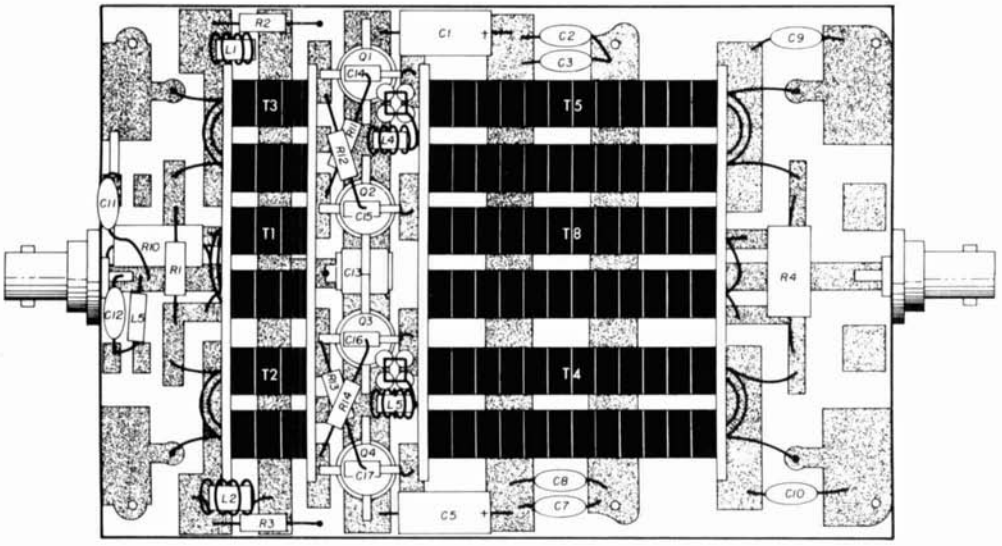
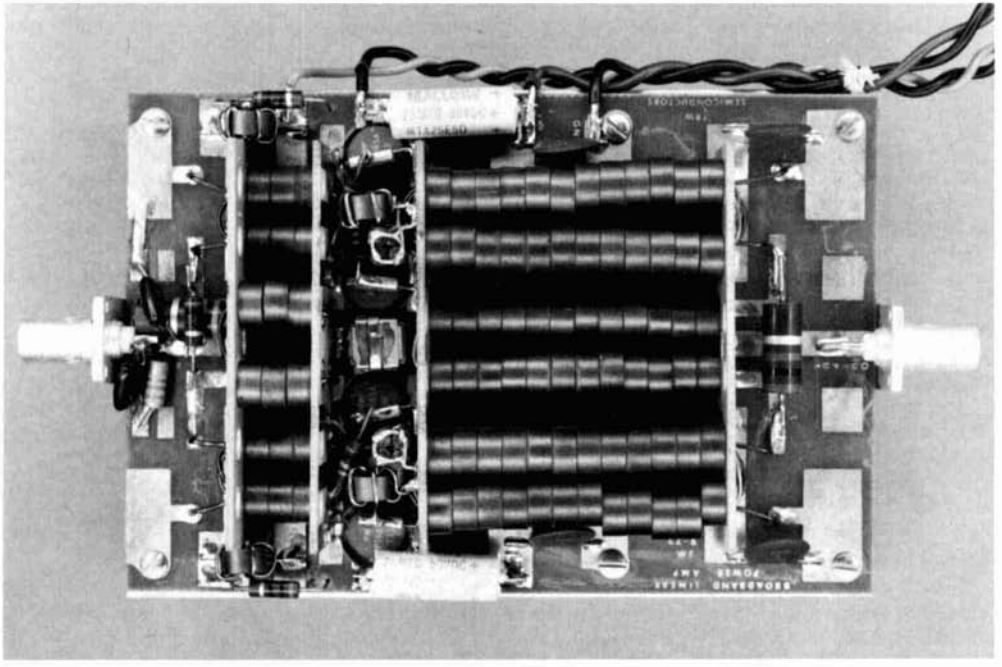



**fig. 11. Component layout for the rf power amplifier. Transformer T6 is underneath T4, T7 is underneath T5.**

the input impedance match have been further tailored by the addition of C11, C12, L5 and R10 at the amplifier input.

The collector feed transformers (T4 and T5) combine with the output matching transformers to form a modified 180-degree hybrid combiner as described by Pitzalis and others.[1] The ferrite mate-

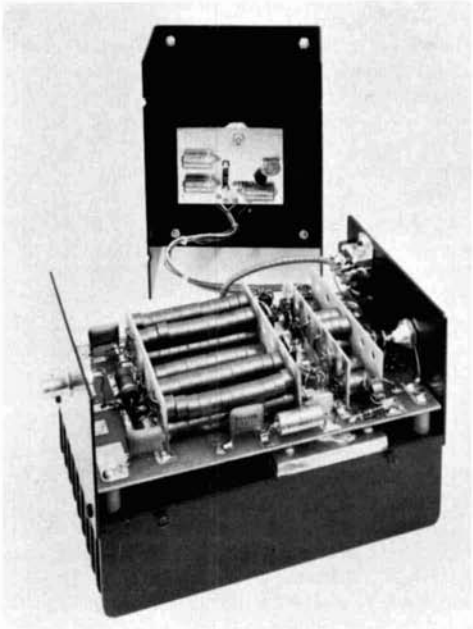
**fig. 12. Completed 320-watt linear power amplifier, showing location of the power transistors, combiner transformers and other components. In this photograph the input is to the left, output is to the right (see fig. 11).**



rial used must have an initial permeability of 800 and the permeability must remain above 200 at 30 MHz. Losses in this ferrite are quite low and the ferrite temperature used is typically less than 20°C at full CW output. The Curie temperature is 150°C minimum (165°C typical).

When winding the transformers, care must be taken to avoid scraping insulation from the wire. Any burrs should be removed from inside the brass tubing and a heavy varnished Formvar-type wire should be used. Do not use thermal strip-away wire because it may break down and short out under high-power rf loads.

The bias control circuit used in the amplifier is of the temperature-tracking, fixed-current type (transistors Q5, Q6 and Q7). The temperature sensing transistor, Q5 (TRW PT9732), is mounted on the heatsink as close as possible to the center of the mounting area of the rf power transistors Q1, Q2, Q3 and Q4.



**Complete 320-watt solid-state linear showing printed-circuit board installed on heatsink. Circuitry on small board mounted on cover is part of the bias-control circuit.**

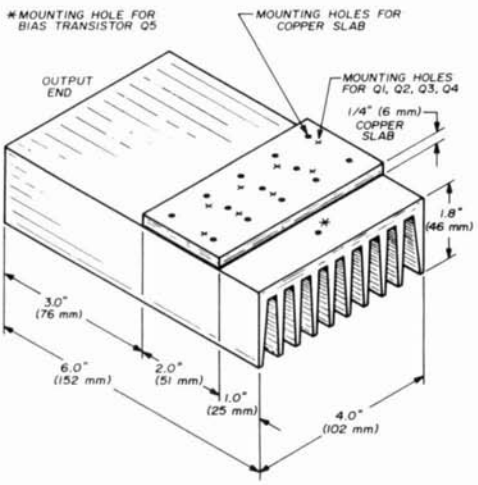



**fig. 13. Heatsink and copper slab hole patterns. The heatsink is a Thermalloy 6157 or similar. All holes in the copper are drilled to pass a 4-40 screw; all holes in the aluminum are drilled and tapped for 4-40 screws. The printed-circuit mounting holes should be located after the PC board is drilled.**

## construction

The printed-circuit board for the 320-watt linear amplifier is shown in **fig. 10**. Parts placement is shown in **fig. 11**. This drawing also contains information on the location of the power supply filter

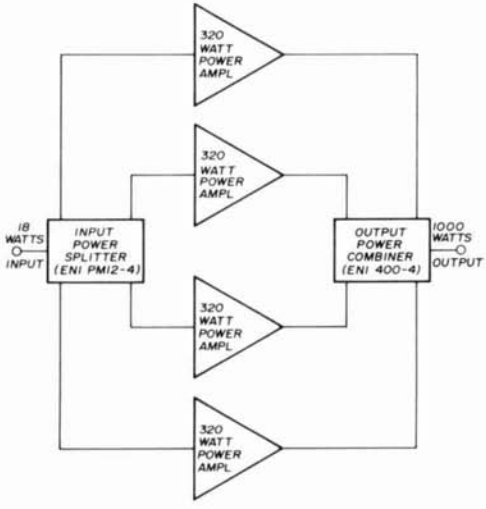



**fig. 14. Four of the 320-watt amplifiers can be combined, as shown here, to provide 1000 watts output over the frequency range from 1.5 to 30 MHz. IMD and drive power for this arrangement are plotted in figs. 15 and 16.**

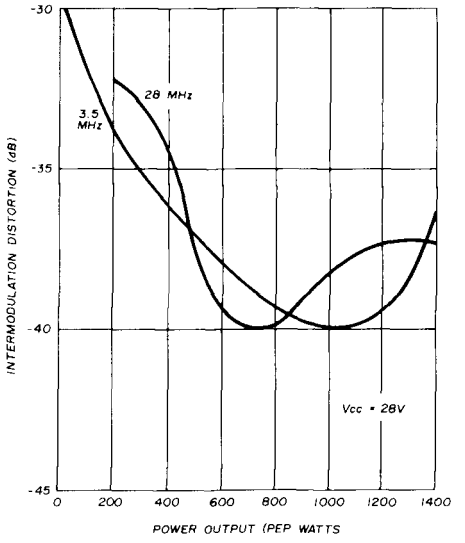



**fig. 15. IMD performance of the 1000-watt linear amplifier.**

components L4/R6 and L3/R5. The location of the collector-to-base feedback networks—C14/R11, C15/R12, C16/R13, C17/R14—can be easily determined from the photographs. Capacitors C2 and C6 (not visible in **fig. 12**) are located on the ground strip. Capacitor C2 is between Q1 and Q2, and C6 is between Q3 and Q4.

Since considerable heat is dissipated by the power transistors, good thermal conductivity between the transistors and the heatsink must be insured. This is accomplished by:

1. Placing a piece of slab copper between the transistor flange and the aluminum heatsink (see **fig. 13**).

2. Sanding smooth the copper slab and the heatsink surface as well as the bottom of the transistor flange.

3. Using thermal conductive compound between the copper slab and heatsink and between the transistor flanges and the copper.

4. Using cooling air for long transmission periods.

*Available from Electronic Navigation Industries, Inc., 3000 Winton Road South, Rochester, New York 14623.

## solid-state kilowatt

To obtain a very conservative 1000-watts rf *output* over the frequency range from 1.5 to 30 MHz, four of the 320-watt amplifiers can be combined using straightforward, commercially available summing circuitry as shown in **fig. 14**. The input power splitter, an ENI model PM12-4, and the output power combiner, an ENI model 400-4, are available from Electronic Navigation Industries.* The overall amplifier operates directly from a 28-volt dc power supply with a typical IMD of -36 to -38 dB at full rated output. Although IMD performance falls off at lower power levels, it is better than -30 dB for all cases (see **fig. 15**).

The drive requirements for the 1000-watt amplifier, plotted graphically in **fig. 16**, vary from approximately 4.5 watts at 3.5 MHz to 18 watts at 28 MHz. As noted previously, a 1000-watt amplifier can also be built with three of the basic 320-watt power amplifiers, but with some increase of IMD harmonics, to -30 dB or so, at the upper power levels.

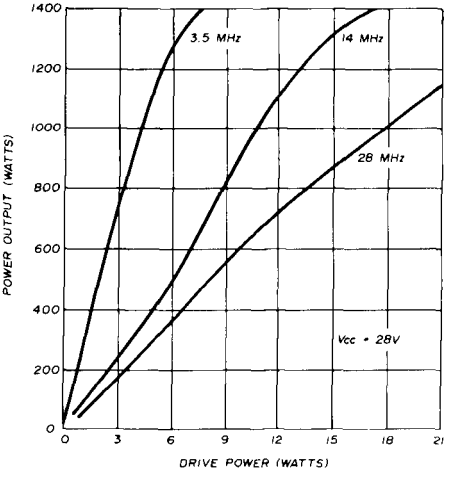



**fig. 16. Drive requirements for the broadband, 1000-watt linear amplifier.**

### reference

1. O. Pitzalis, Jr., and T. Couse, "Broadband Transformer Design for RF Transistor Power Amplifiers," U.S. Army Electronics Command, Fort Monmouth, New Jersey

**ham radio**

# how to calculate wind loading on towers and antenna structures

A discussion of the effect of wind loading on self-supporting towers, guyed towers and other antenna structures

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**Almost all amateur** operators are involved at one time or another in the erection of an antenna tower. The construction of a tower to withstand the elements, most notably wind, is of prime importance to the successful operation of an amateur station. Yet, very few amateurs bother to calculate the wind forces, or wind loading as it is technically known, on their antennas or towers. This may be because there is very little material on this subject available in the amateur literature.

Wind loading is generally considered to be a civil engineering subject and therefore not suitable for an electronic engineering publication, but when properly organized, the subject is relatively straight forward, requiring at most a knowledge of high school physics. Actually, I have seen subjects that are much more complex, both physically and mathematically, successfully treated in *ham radio* and similar magazines.

The purpose of this article is to organize and present the subject of wind loading on radio towers in such a manner that the average amateur who has the skill and ability to assemble and operate an amateur station can calculate the wind forces trying to overturn his tower. The wind loading on parabolic antennas and

the use of guy wires will also be briefly discussed.

Much of the material in this article has been taken from Electronic Industries Association (EIA) Standard RS-222-B, dated December, 1972.[1] I highly recommend that anyone planning to construct an antenna system obtain a copy of this standard as it is easy reading and contains much interesting and useful information beyond what will be presented here.

Calculating the wind loading on an antenna is a relatively simple procedure: First, determine the projected area of the tower and antenna. Then, by applying a very simple formula the area can be converted into a horizontal force for any wind velocity. For a free-standing (unguyed) tower which is constrained only at the base, this horizontal force develops an overturning moment which the tower and foundation must resist. The situation for a guyed tower which is constrained at both top and bottom is slightly different in that tensions in the guy wires must also be calculated; these will also be considered. These calculations are all very simple and will be discussed using examples.

## projected area

For the tower and beam example, I will use a forty-foot (12.2-meter) tower made of four ten-foot (3-meter) sections with a 20-meter beam on the top; this is typical of installations used by amateurs. A typical 10-foot (3-meter) section is shown in **fig. 1**; as can be seen, the tower has a triangular cross-section with six sets of cross braces per side. The main structural members are at the corners and are composed of 1¼-inch (3.2-cm) OD steel tubing; the cross-bracing consists of 3/8-inch (10-mm) OD rod, each rod 12-inches (30.5-cm) long.

The projected area of each corner leg is therefore 1¼ x 120 = 150 square inches (3.2 x 304.8 = 975.4 square cm). Since there are two legs per face

2 x 150 = 300 square inches

2 x 975.4 = 1950.8 square cm

For the cross-braces we have

0.375 x 12 x 2 = 9 square inches

0.95 x 30.5 x 2 = 58 square cm

As there are six sets of braces per ten-foot (3-meter) section

6 x 9 = 54 square inches

6 x 58 = 348 square cm

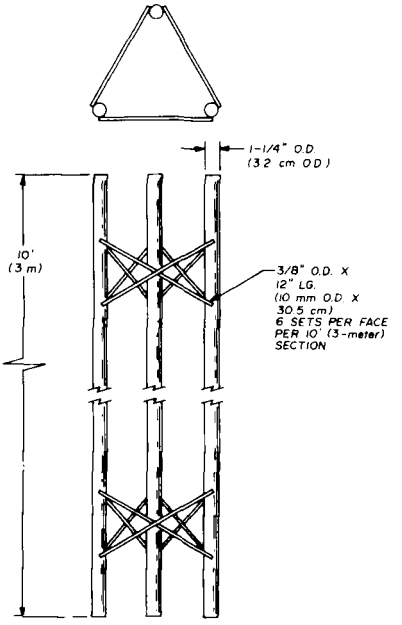



**fig. 1. Dimensions of a typical 10-foot triangular tower section.**

Hence, the total surface area is

300 + 54 = 354 square inches

1936 + 348 = 2284 square cm

This is equal to (354/144) = 2.46 square feet (0.228 square meters) per ten-foot (3-meter) section, as there are 144 square inches per square foot.

It is important to notice that we did not calculate the surface area of the cylindrical structural members, but instead calculated the projected area. The projected area may be defined as the outline area or as the area of a shadow cast by the member. If the structural member has a flat surface, such as a

wooden 2x4 or steel angle-iron, the projected area and surface area will be the same, but this is not the case for structural members with a cylindrical cross-section.

The reason for using the projected area can be explained as follows: When a cylindrical surface has a uniform pressure applied as shown in **fig. 2**, the components applied close to the tangential points, such as vectors A and C, exert a relatively small component on the cylinder parallel to their own direction. The radial components that they exert are equal and opposite and, hence, cancel out. The components applied at the center, such as vector B, are fully effec-

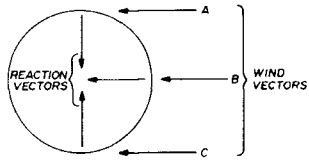



**fig. 2. Diagram of wind and reaction vectors on a cylindrical surface.**

tive in creating horizontal force on the structural member. It can be shown mathematically that the wind resistance is proportional to the projected area and not the surface area.

In the case of a cylinder the wind force is further reduced because the streamlining effect of the cylinder makes the wind force less than for a flat surface of the same projected area. Paragraph 2.2.4 of reference 1 states that, "the pressure on cylindrical surfaces shall be computed as being 0.66 of that specified for flat surfaces." This means that when dealing with cylindrical structural members, the wind forces are two-thirds those of flat surfaces, or to say the same thing in a different manner, the projected area of the cylindrical member may be reduced to 0.66 of its actual value.

In the case of open face or lattice towers, one other factor must be considered. That is the effect of wind blowing through the tower and against the back structural elements as this area is also effective in developing a horizontal force. Paragraph 2.2.5 of reference 1 states that,

> "For open face (latticed) structures of square cross section, the wind pressure shall be applied to 1.75 times the normal projected area of all members in one face. For open face (latticed) structures of triangular cross section, the wind pressure shall be applied to 1.5 times the normal projected area of all members in one face. For closed face (solid) structures, the wind pressure shall be applied to 1.0 times the normal projected area."

The only type of solid structures I can think of that would be used by amateurs are irrigation tubing, telephone poles or wooden 2x4s bolted together.

It can be noted when dealing with lattice-type towers with a triangular cross section, and using the cylindrical structural members which are so popular in amateur work, the 1.5 triangular factor, when multiplied by the 0.66 cylindrical factor, gives 0.66 x 1.5 = 1. Therefore, both factors can be neglected when dealing with this type of tower. Although these factors may be neglected, they should not be forgotten!

## wind force

So much for area involved. The problem now is to convert that area into a force. EIA Standard RS-222-B states in paragraph 2.3 that the wind pressure P in pounds per square foot is given by

$$P = 0.004\ V^2 \qquad (1)$$

where V is the wind velocity in miles per hour and 0.004 is the wind conversion factor (includes a gust factor and a drag coefficient for flat surfaces).* Note that the wind force is proportional to the wind velocity squared.

It may be pointed out that the exponent on the velocity, 2 in this case, is itself a function of the velocity. The

*In metric terms the formula is $P = 0.0075\ V^2$, where P is in kilograms per square meter and V is velocity in kilometers per hour.

factor 2 is a good average value for wind velocities in, say, the 30- to 100-mph (48- to 161-kph) region. For extremely low velocities, say, less than about 10-mph (16 kph), wind force is linear with velocity. As wind velocity approaches the trans-sonic region, the exponent becomes very high. This is why supersonic aircraft require such large engines.

It is interesting to digress for a moment and consider **eq. 1** in a different light. By applying Newton's third law (action and reaction), **eq. 1** also gives the wind resistance when an object is driven at a given velocity through still air. For example, a standard size automobile presents a frontal area of about 25 square feet (2.3 square meters) so at 60 mph (96.6 kph) requires

$P = 0.004 \times 60^2 \times 25 = 360$ pounds of force

$P = 0.0075 \times 96.6^2 \times 2.3 = 161$ kilograms of force

just to overcome wind resistance. Note that increasing the velocity by $\sqrt{2} = 1.414$ (from 50 to 70 mph [80 to 113 kph], for example) will double the wind resistance. Couple this with the fact that the efficiency of a typical automobile engine is much less at 70 (113 kph) than at 50 mph (80 kph) — it's easy to see why fuel consumption increases astronomically at higher speeds.

## wind-loading zones

Returning to our original problem, since we have calculated the projected area, this can be converted to a horizontal force at any given velocity by using **eq. 1**. The only question remaining is what wind velocity to design for. Fortunately, RS-222-B comes to our aid again. **Table 1** and the accompanying map of **fig. 3** give the recommended horizontal design wind pressures in pounds per square foot and kilograms per square meter for various parts of the United States (windloading zones) and for various heights above ground. RS-222-B also has a table giving the zones by states and counties, which will not be reproduced here because of space limitations. If you cannot pinpoint your location precisely from **fig. 3**, you may want to consult the table of counties in RS-222-B. You may also assume the more severe wind-loading zone.

**table 1. Recommended horizontal design wind pressures in pounds per square foot (kilograms per square meter given in parenthesis). Wind-loading zones for the United States are shown in fig. 3.**

| height zone (above ground) | wind-loading zone A | B | C |
|---|---|---|---|
| Portion of tower 300 feet (19.4 meters) and under | 30 (146.5) | 40 (195.3) | 50 (244.1) |
| Portion of tower 301 to 650 feet (91.7 to 198 meters) | 35 (170.9) | 48 (234.3) | 60 (292.9) |
| Towers 651 feet (198.5 meters) and higher shall be designed for uniform wind pressure for their entire height | 50 (244.1) | 65 (317.3) | 85 (415.0) |

The data for both **table 1** and **fig. 3** were obtained by statistical methods from long-term weather observations based on wind velocities that should not be exceeded, on the average, more than once every 50 years. The work is described in a paper by H.C.S. Thom.[2] A later paper on this same subject has also been published by Thom.[3] Both Thom papers are highly statistical and the EIA map offers much more usable information for the average individual.

Most amateur towers will fall in the 300-feet-and-under (91.4 meters) category for which **table 1** gives wind loading of 30, 40 or 50 pounds per square foot (146.5, 195.3 and 244.1 kg per square

meter) respectively, for wind zones A, B and C. Putting these numbers into **eq. 1** gives wind velocities of 86.6, 100 and 112 miles per hour (139.4, 161 and 180 kilometers per hour). Since I live in the metropolitan Washington, D.C., area which is clearly in wind loading zone A, I will design for wind loading of 30 pounds per square foot (146.5 kg per square meter) or 86.6 mph (139.4 kph).

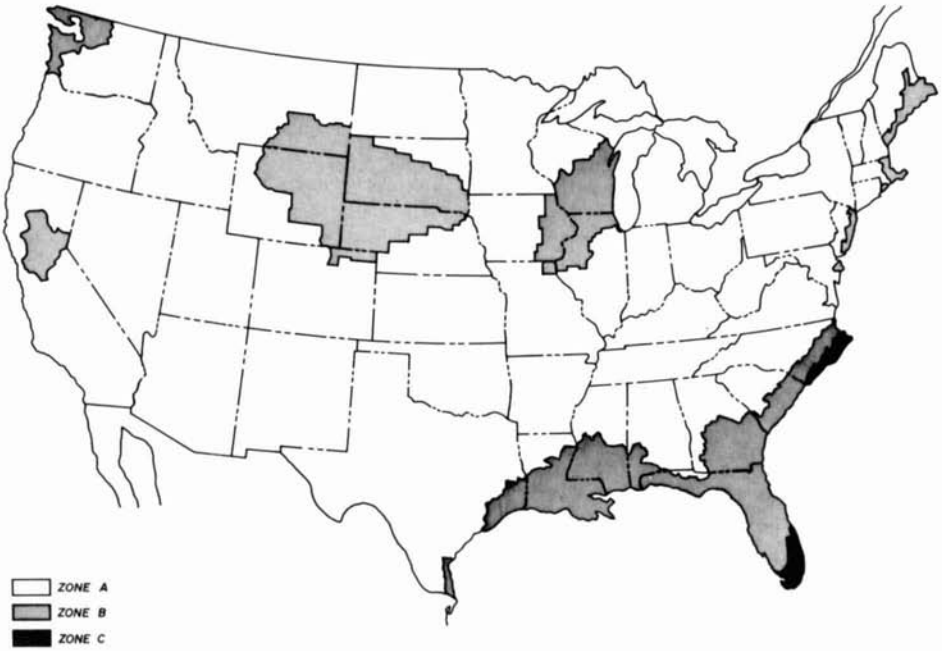



**fig. 3. Location of wind-loading zones in the United States (from EIA Standard RS-222-B).**

## practical example

Returning to the problem, we have already calculated that the projected area of a ten-foot (3-meter) section of tower is 2.46 square feet (0.228 square meter). Applying correction factors of 0.66 for cylindrical structural members and 1.5 for a triangular tower gives

2.46 x 0.66 x 1.5 = 2.44 square feet, (0.228 x 0.66 x 1.5 = 0.226 square meter) projected area

Assuming a wind velocity of 86.6 mph (139.4 kph) (or 30 pounds per square foot [146.5 kg per square meter] — gives a total horizontal force of

(2.44 square feet) x (30 lb/sq ft) = 73.2 pounds, horizontal force

(0.226 square meter) x (146.5 kg/m$^2$) = 33.2 kg, horizontal force,

For later computational reasons we will assume this force is uniformly distributed along the length of the tower. This results in a loading of

$$\frac{73.2 \text{ lb}}{10 \text{ ft}} = 7.32 \text{ pounds per foot of tower}$$

$$\frac{33.2 \text{ kg}}{3 \text{ meters}} = 11.1 \text{ kg per meter of tower}$$

As previously stated, I intend to use four 10-foot (3-meter) sections to give the tower 40-feet (12.2-meters) height. This gives the situation shown in **fig. 4** for a total horizontal force of

F = 40 x 7.32 = 292.8 pounds

F = 12.2 x 11.1 = 135.4 kilograms

Because the tower is constrained at the bottom and free at the top (unguyed), the effect of this force is to cause the

tower to rotate about the horizontal axis through its base, i.e. fall down.

In physics, a force that causes an object to rotate is called a *moment* or a torque and is defined as a force multiplied by a distance or

$$\text{moment} = \text{force} \times \text{distance} \qquad (2)$$

The units are pound-feet (dyne-cm).

*The problem now is, "How do we* translate a uniformly distributed horizontal force into a single overturning moment?" Luckily, the answer is quite simple; a uniformly distributed force will generate the same moment as a single force with the same total value acting at a point midway on the structure. Hence a uniformly distributed force of 7.32 pounds/foot (11.1 kg/meter) along the tower will generate the same moment as a single force of 292.8 pounds (135.4 kilograms) acting at the mid-point of the tower. This is shown in **fig. 5.** This gives an overturning moment of

$M = 20 \times 292.8 = 5856$ pound-feet

$M = 6.1 \times 135.4 = 825.9$ kilogram-meters ($8.2 \times 20^{10}$ dyne-cm)

This is the moment developed by the tower alone; now let's put a HyGain Model 203-BA three-element, 20-meter beam on the top of the tower which,

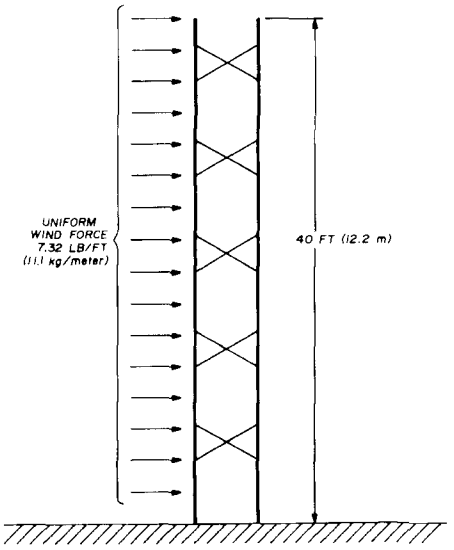



**fig. 4. Uniform horizontal force on a tower.**

according to the manufacturer, has an area of 3.08 square feet (0.286 square meter). A wind loading of 30 pounds per square foot (146.5 kg/m$^2$) (86.6 mph – 139.4 kph) will develop a horizontal force of

(30 lb/ft$^2$) x (3.08 ft$^2$) = 92.4 pounds

(146.5 kg/m$^2$) x (0.286 m$^2$) = 41.9 kilograms

on the antenna which in turn will generate a moment of

$M = 92.4 \times 40 = 3696$ pound-feet

$M = 41.9 \times 12.2 = 511.2$ kilogram-meters ($5.01 \times 10^{10}$ dyne-cm)

at the top of the tower. The total overturning moment acting on the tower is then

$M = 3696 + 5856 = 9552$ pound-feet

$M = 511.2 + 825.9 = 1337.1$ kilogram-meters ($13.1 \times 10^{10}$ dyne-cm)

This combination is shown in **fig. 6.** This may be considered as a single force of 9552 pounds acting at a distance of one foot above the ground, a force of 9552/20 = 477.6 pounds acting 20 feet up the tower, as a force of 238.8 pounds acting at the top of the tower, or any other combination of force multiplied by distance whose product is 9552 pound-feet as shown in **fig. 6.**

In metric terms, this may be considered as a single force of 1337.1 kilograms acting at a distance of one meter above the ground, a force of 1337.1/6.1 = 219.2 kilograms operating 6.1 meters up the tower, as a force of 109.6 kilograms acting at the top of the tower, or any other combination of force multiplied by distance whose product is 1337.1 kilogram-meters.

The antenna and tower combination used in this example is relatively modest compared with some antennas, and yet, the overturning moment is nearly 5 tons on a one-foot arm!

The tower must be strong enough to transmit this moment to the foundation; the foundation, in turn, must be designed

to have a moment of its own that, when combined with the soil resistance, will resist this overturning moment with an acceptable margin of safety if the tower is to remain standing.

The design of tower structures themselves would take us into the subjects of structural mechanics and strength of materials; foundation design would add soil mechanics. These subjects are all well beyond the scope of this article. We will, however, briefly discuss guying since guy wires can significantly reduce foundation requirements.

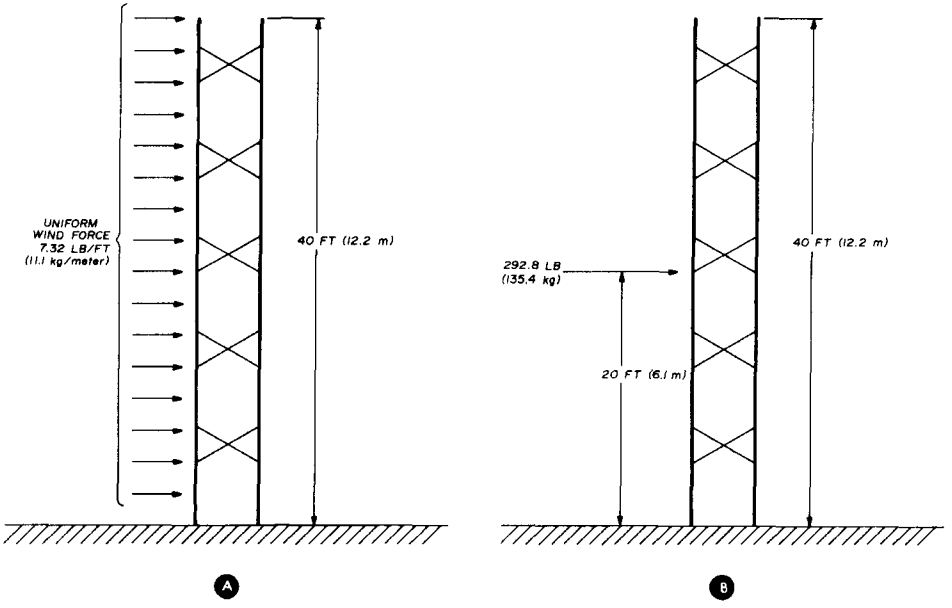



**fig. 5. The overturning moment caused by the uniform wind force in (A) is exactly the same as the overturning moment generated by the single mid-tower force in (B).**

## guying

Guyed towers have the advantage of requiring much less structural material than self-supporting towers. As an example, a self-supporting 700-foot (213.4-meter) steel tower of conventional design will weigh about 460,000 pounds (208,651 kilograms). A comparable guyed tower will weigh about 200,000 pounds (90,718 kilograms) including the weight of the guys. It should be remembered that a guyed tower must also be capable of supporting the guy wires. While very few amateurs are so fortunate, or unfortunate, as to have a 700-foot (213.4-meter) tower, the savings in material of a guyed tower is obvious.

A disadvantage of guyed towers is the additional real estate required for guy wires. In a commercial installation, the designer would compare the cost of real estate against the cost of additional steel and concrete required to make the tower self-supporting. For the amateur who must install his tower in a residential neighborhood additional considerations are aesthetics and the whims of his wife. This last consideration, unhappily, is not amenable to a rigorous engineering analysis.

Assume now that the same 40-foot (12.2-meter) antenna and tower as previously described has a set of guy wires 30-feet (9.1-meters) from the base of the tower, as shown in **fig. 7.** From the Pythagorean theorem the length of the guy wire is

$$\sqrt{40^2 + 30^2} = 50 \text{ feet (15.2 meters)}$$

The angle with respect to ground is

$$\theta = \tan \frac{40}{30} = 53.1 \text{ degrees}$$

For the sake of simplicity, we will consider only one guy wire. This is actually the case when the wind is blowing toward the tower from the direction in which the guy wire under consideration is anchored.

It is not generally appreciated, but a guy wire converts an overturning moment into increased downward stress on the tower. As previously noted, the total horizontal force in this example is 293 pounds (132.9 kilograms) on the tower plus 92 pounds (42 kilograms) on the antenna. Since the top of the tower is now constrained by the guy wires, the overturning moment is zero. For this reason the structural requirements on the tower and foundation are greatly reduced because these items need only support the weight of the assembly and the additional load imposed by tension in the guy wires.

Because the horizontal force on the tower – 293 pounds (132.9 kilograms)–is uniformly distributed over the length of the tower, we will assume that one-half the constraining force – 146.5 pounds (66.5 kg) – is located at the top of the tower and one-half at the bottom. The horizontal force on the antenna – 92 pounds (41.7 kg) – will be assumed to be located entirely at the top of the tower. This is shown in **fig. 8.**

This allocation of reactions given may seem arbitrary, but it is difficult to visualize a mechanism by which the 92-pound (41.7-kilogram) horizontal force of the antenna can be transmitted to the base of the tower without generating a moment. Also, if there is any error, the forces in the guy wire will be overestimated and not underestimated. The tension in the guy wire may be resolved into a horizontal and a vertical component. The horizontal component must be 238.5 pounds (108.2 kilograms) since it must exactly equal the horizontal windload (146.5 + 92 pounds or 66.5 + 41.7 kilograms). The tension in the guy wire itself may be calculated by setting up a vector diagram as in **fig. 9.**

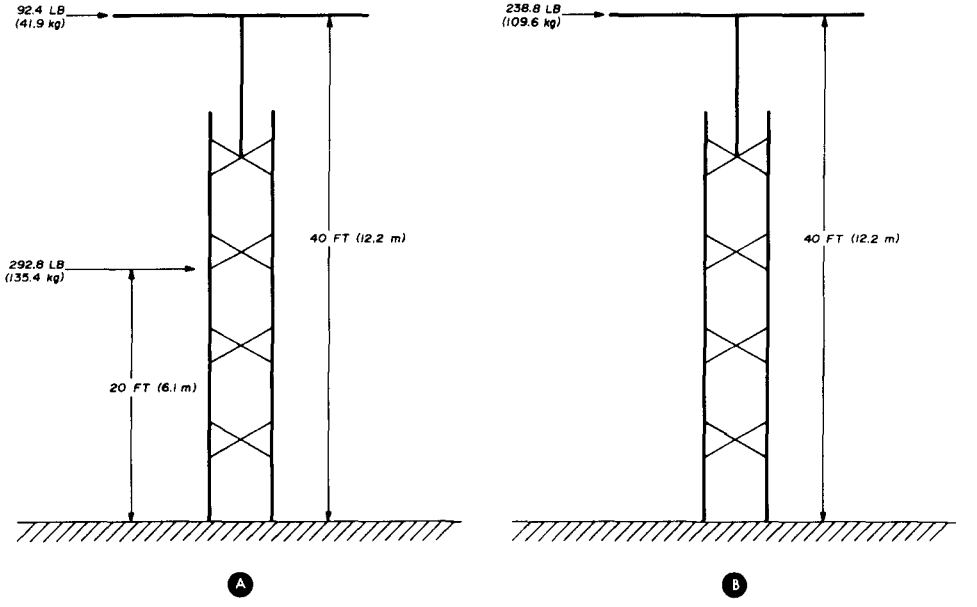



**fig. 6. The overturning moment in (A) is the same as the overturning moment in (B). See text for calculations.**

$$F_{gw} = \frac{238.5}{\sin 39.9^\circ} = 397.2 \text{ pounds}$$

$$F_{gw} = \frac{108.7}{\sin 36.9^\circ} = 181 \text{ kilograms}$$

where $F_{gw}$ is the force on the guy wire and the additional vertical component which must be resisted by the tower is

$$F_v = \frac{238.5}{\tan 36.9^\circ} = 318 \text{ pounds}$$

$$F_v = \frac{108.2}{\tan 36.9^\circ} = 144.2 \text{ kilograms}$$

In other words, an 86.6-mph (139.4 kph) wind will develop a tension of 397.2 pounds (180.2 kilograms) in the guy wire and an additional vertical load of 318 pounds (144.2 kilograms) on the tower. This vertical load is more than the weight of the antenna! It should also be emphasized that these loads are in addition to the vertical loads caused by the initial tension in the guy wires.

The vertical load can be reduced by making the guy wires longer; i.e., moving the bottom end of the guy wire farther out from the base of the tower. As the guy wire approaches the horizontal, the vertical component approaches zero and guy-wire tension approaches the total wind load at the top of the tower — 238.5 pounds (108.2 kilograms).

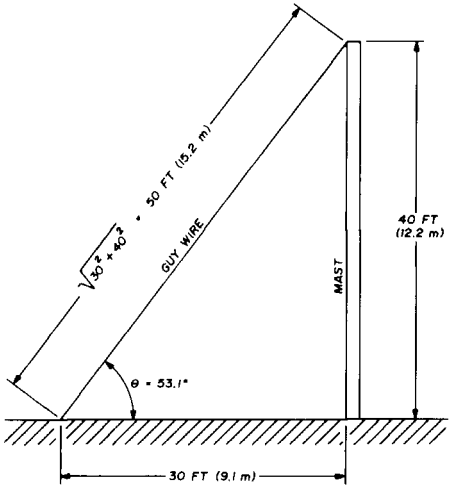



**fig. 7. Guy wire arrangement. Length of guy is easily calculated by use of the Pythagorean theorem.**

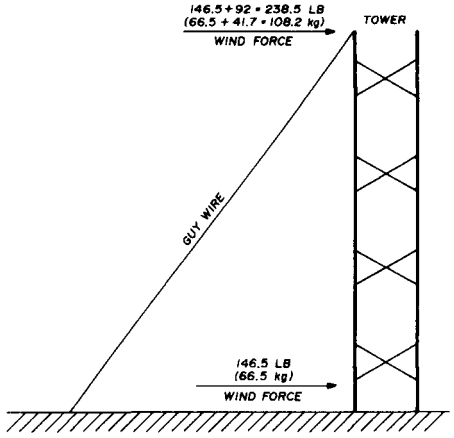



**fig. 8. Horizontal forces of tower and antenna on a guyed tower.**

So far we have considered the involvement of just one guy wire. When considering two guy wires you might think that for the same horizontal wind load, the tension in each guy wire would be one-half the tension for one wire. Unfortunately, it does not work out that easily. Let's consider a tower held by three guy wires at 120° intervals, as shown in **fig.10.** This is a typical arrangement. If the wind blows in the direction of arrow A, guy wire number-1 takes the wind load and the situation is as explained for one guy wire. If the wind blows as shown by arrow B, things are slightly different, as shown by the vector diagram in **fig. 11.** Using the same numbers as in the example above, the horizontal wind load of 238.5 pounds (108.2 kilograms) is shared equally by guy wires 1 and 2, so we allow 119.3 pounds (54.1 kilograms) on each. In this case the third guy wire carries none of the load. The horizontal force in the direction of each guy wire is thus

$$F_H = \frac{119.3}{\cos 60^\circ} = 238.5 \text{ pounds}$$

$$F_H = \frac{54.1}{\cos 60^\circ} = 108.2 \text{ kilograms}$$

As in the preceeding example, the tension on each guy wire is 397.2 pounds (180.2 kilograms) and the vertical com-

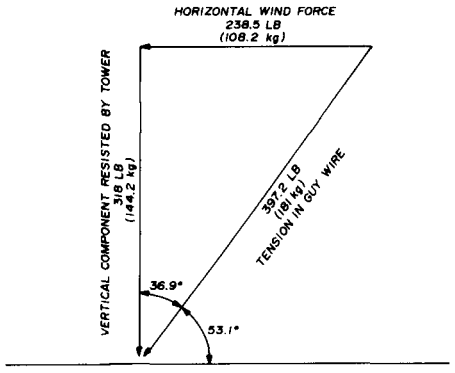



**fig. 9. Vector diagram of guy wire tension. Note that the vectors represent reactions in the guy wire and not the forces acting on the guy.**

ponent for each guy wire is 318 pounds (144.2 kilograms) — a total of 715.2 pounds (324.4 kilograms). The total is thus twice the vertical load generated by a wind blowing in the same direction as any one guy wire. It is easy to see that wind loads can add up pretty quickly!

The use of guy wires imposes a penalty in that the tower and foundation must be designed for greater vertical loads. The advantage of guy wires is that the tower and foundation need not be designed to resist an overturning moment. The tower designer's choice is between vertical loads and overturning moments. Also, it is much more expensive to build to resist the overturning moment than it is to withstand a straight vertical load.

An important factor to be considered in the installation of a guyed tower is the initial tension in the guy wires. If the guy wires are too loose, the tower will sway excessively. If the guys are pulled too tightly, an excessive vertical load may be put on the tower. In fact, in large installations it may be possible to buckle the tower with excessive initial tension. It is therefore necessary to compromise between stiffness and reasonably sized structural members in the tower.

## antenna size

In an earlier example we assumed the area of the antenna was known from the manufacturer's data. If the antenna is homemade, I suggest that you calculate its area the same as you would for the tower. Consider each element separately and apply the cylindrical correction factor. Calculate the area looking down the axis of maximum radiation and also at right angles to this axis. Choose the area that is larger.

Because of the increasing interest in 1250 MHz and above, and the easy availability of parabolic antennas with solid reflectors, it is both interesting and instructive to apply the above principles to a parabolic dish and compare these with a tower. We will assume a dish with a 10-foot (3-meter) diameter and a 100 mph (161 kph) wind. From **eq. 1** the wind pressure caused by a 100-mph (161 kph) wind is 40 pounds per square foot (195.3 kilograms per square meter). The projected area is

$$\frac{\pi d^2}{4} = \frac{\pi(10)^2}{4} = 78.5 \text{ square feet}$$

$$\frac{\pi d^2}{4} = \frac{\pi(3)^2}{4} = 7.3 \text{ square meters}$$

and the total horizontal wind pressure is

$(78.5\ ft^2) \times (40\ lb/ft^2) = 3140$ pounds

$(7.3\ m^2) \times (195.3\ kg/m^2) = 1426$ kg

If a 10-foot (3-meter) antenna is to look at the horizon to see a rising

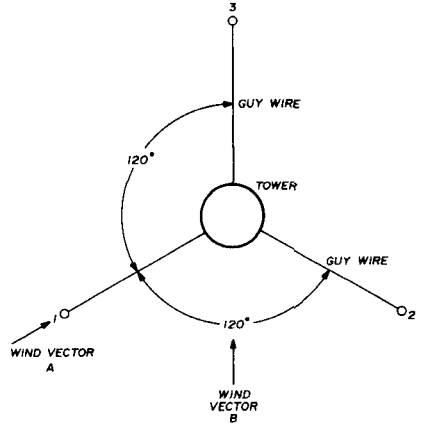



**fig. 10. Tower held by three equally displaced guy wires.**

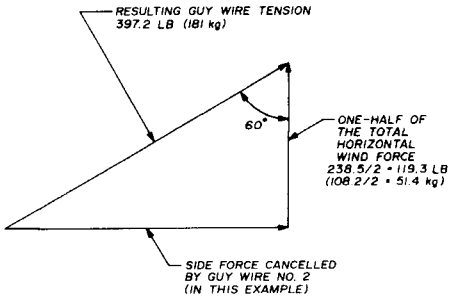



**fig. 11. Vector diagram of loads in the case of two guy wires.**

satellite, as shown in **fig. 12,** the mounting structure must be at least 6-feet (1.8-meters) tall to provide ground clearance. Thus, the minimum overturning moment will be

(3140 lb) x (6 ft) = 18,840 pound-feet

(1426 kg) x (1.8 m) = 2566.8 kilogram-meters ($25.17 \times 10^{10}$ dyne-cm)

Note that a 10-foot (3-meter) parabolic dish mounted on a 6-foot (1.8-meter) support has approximately twice the overturning moment of a 3-element, 20-meter beam mounted on a 40-foot (12.2-meter) tower.

Unfortunately, this is not the whole story. The above calculations are for a head-on wind. Experiments have shown that the greatest wind force on a parabolic antenna occurs not for a head-on condition, but when the wind is blowing at an angle to the antenna axis as shown in **fig. 13.**

For the antennas of one manufacturer[4], this wind angle is 56° and the maximum force is 10-percent higher than for a zero-degree wind angle. The reason for this is that at some wind angles the rear surface of the dish acts as an air-foil which develops *lift* in a manner similar to an aircraft wing, thereby increasing the horizontal force on the antenna.

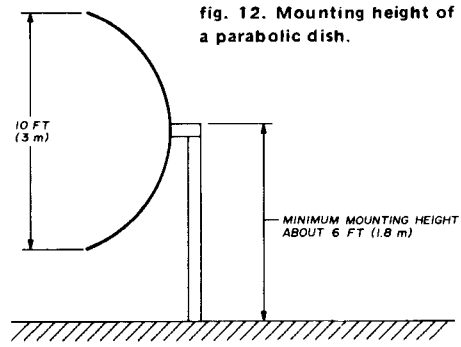
Because this extra force depends on the shape of the antenna, it may not be the same for all parabolic antennas. The antenna parameter that has the greatest effect on this additional lifting force is probably the focal length of the antenna as this determines how deep the dish must be for a given diameter and hence will effect the lift/drag coefficient of the dish. It is not practical to give lift coefficients or angles of maximum wind loading for all cases, but a 10-percent increase in wind loading due to lift at an angle of 56° is probably a good approximation for most parabolic antennas.

The relatively large wind loading of a parabolic dish can be considerably reduced by perforating the dish. If the holes are small compared to the wavelength of operation, the effect on antenna performance will be negligible, but the wind loading will be decreased considerably.

## ice loading

The preceding material has not considered the effect of ice. The magnitude of the additional load imposed by ice will depend on your location. Do you live in Miami, Florida, or Bismarck, North Dakota? The effect of ice, of course, is to increase the projected area of the structural members, thereby increasing the wind load. Unfortunately, it frequently occurs in many parts of the country that the strongest winds occur during ice storms, thereby compounding the problem. If you feel you should consider ice loads, I suggest you contact the chief engineer of a local broadcast station and find out what ice thickness his towers are designed to handle. Calculate the projected areas when loaded with the maximum expected thickness of ice. Remem-

**fig. 12. Mounting height of a parabolic dish.**



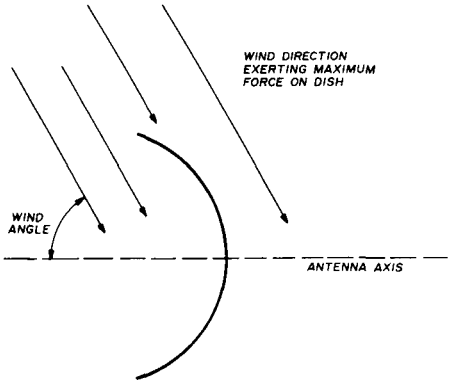



**fig. 13. Relationship of parabolic antenna and direction of wind exerting maximum force.**

ber, too, that ice coats both sides of the structural members so that a 1/2-inch (13 mm) radial thickness of ice will increase the overall dimensions by 1 inch (25 mm).

## summary

In the above material I have shown how to calculate the overturning moments caused by wind forces on antenna structures of the type used by most amateurs. These forces can be appreciable, especially when augmented by ice. Parabolic antennas have even higher wind loadings. I have also discussed the use of guy wires, and have shown how these eliminate the overturning moment but increase the vertical loads on the tower.

The procedure for calculating the wind loading on a conventional tower/antenna combination may be summarized as follows:

1. Calculate the projected area of the tower.

2. Apply the appropriate correction factor for cylindrical surfaces and/or triangular or square cross section, as necessary.

3. Determine the maximum expected wind velocity.

4. Calculate the horizontal force on the tower.

5. Determine the effective area and horizontal force on the antenna.

6. If the tower is guyed, calculate the tension in the guy wires due to wind loading and determine the additional vertical loading of the tower.

7. If the tower is free standing, determine the moments on both the tower and antenna separately, and add.

The wind loading on a parabolic dish is calculated in the same manner as on any other structure, but maximum wind loading will occur at an angle to the main antenna beam and the numbers will be surprisingly high. Towers, like people, can carry only a limited load before they start to sway. A good man knows his own limit; a good amateur knows his tower's limit.

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1. Electronic Industries Association (EIA) Standard RS-222-B, December, 1972, available from EIA, 2001 Eye Street, NW, Washington, D.C. 20006, price, $4.50.
2. H.C.S. Thom, "Distribution of Extreme Winds in the United States," *Proceedings of the American Society of Civil Engineers, Journal of the Structural Division,* April, 1960, page 11.
3. H.C.S. Thom, "New Distribution of Extreme Winds in the United States," *Proceedings of the American Society of Civil Engineers, Journal of the Structural Division,* July, 1968, page 1787.
4. *Bulletin 1015B*, The Andrew Corporation, 10500 West 153rd Street, Orland Park, Illinois 60462.

**ham radio**

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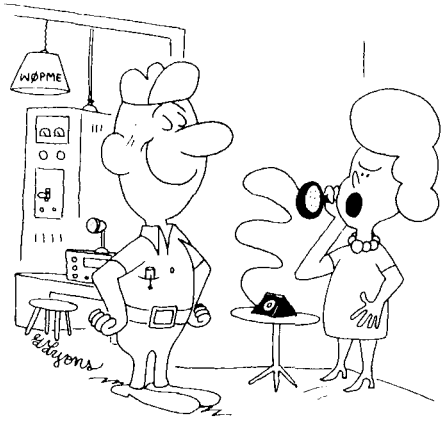


**"Right now he's out of this world . . . . He just bounced a signal off of the moon!"**

# scanning receivers for two-meter fm

A discussion of vhf scanner-monitors, how they work, and how they may be used on vhf fm

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**For many years** vhf fm monitor receivers have enjoyed a modest but reasonably steady popularity with a variety of police officers, firemen and assorted buffs, both amateur and professional. Those early models suffered from most of the same ills which blessed contemporary amateur vhf equipment: instability, difficult tuning and so forth.

The introduction of crystal-controlled, solid-state models increased the popularity of the monitor receiver within the original market but still did not cause a widespread interest among amateur radio operators. In those days, you will recall, two-meter activity was mostly a-m, scattered over a relatively large portion of the band, with no definite channelization outside of a few local net frequencies.

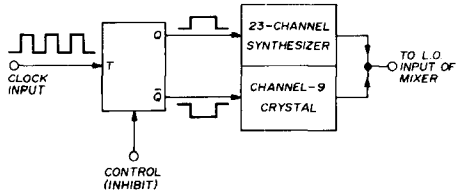
Newer monitor receivers couple crystal control with the ability to search through many channels for activity by using digital logic techniques for scanning. The scanner receiver sequentially looks at four, six, eight or even ten channels prechosen by the user. Amateur use of monitor receivers has increased due to both the availability of reasonably priced models and the channelization of our own two-meter fm activity.

## simple scanner

Dual-receive Citizens Band equipment is neither vhf-fm nor amateur but is sufficiently simple and representative enough to warrant our consideration—if only for instructional purposes!

CB scanners were developed so that a single unit could be used to simultaneously monitor a regular working channel and the national emergency channel. The

**fig. 1. Block diagram of a typical dual receive CB scanner receiver. A J-K flip-flop alternately grounds the 23-channel synthesizer crystal bank, then the Channel-9 crystal, permitting simultaneous monitor capability.**



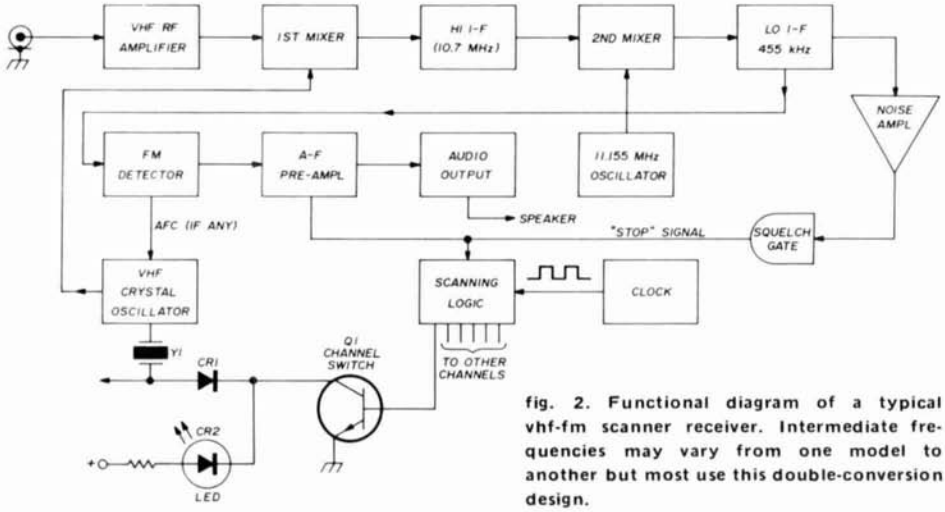



**fig. 2. Functional diagram of a typical vhf-fm scanner receiver. Intermediate frequencies may vary from one model to another but most use this double-conversion design.**

scanner logic switches the receiver back and forth between the channel selected by the multi-crystal synthesizer and channel 9. An increase in the agc voltage, indicating that a station is in the pass-band, causes the scanner to stop seeking and latch onto the signal. Basic operation of the circuit is shown in **fig. 1**. A J-K flip-flop selects which local oscillator is in control of the receiver at any instant of time. An *inhibit* signal causes the circuit to latch when the agc voltage is above a certain level.

**Scan Monitor manufactured by Pace is typical of scanners used by amateurs for two-meter fm. (Photo courtesy Pace).**

## vhf scanners

A typical vhf fm scanner is usually a double-conversion receiver such as that shown in **fig. 2**. A local oscillator, operating from crystals selected by the scan logic, is connected to a mixer where it beats against the incoming rf signal to produce a high i-f in the 10- to 13-MHz range, with 10.7 MHz being most popular. A second mixer heterodynes the output of another crystal oscillator (11.155 MHz in this case) to produce a low i-f (usually 455 kHz). This signal is then handled by the receiver i-f and detector stages in the usual manner.

The squelch circuit of the monitor receiver does more than just keep the output quiet in the absence of a signal: it provides the *stop* command signal to the scanner. Without this ability scanning would be little worse than a useless nuisance.

## scanning logic circuits

**Fig. 3** shows the partial schematic of a scanning circuit. A unijunction transistor,

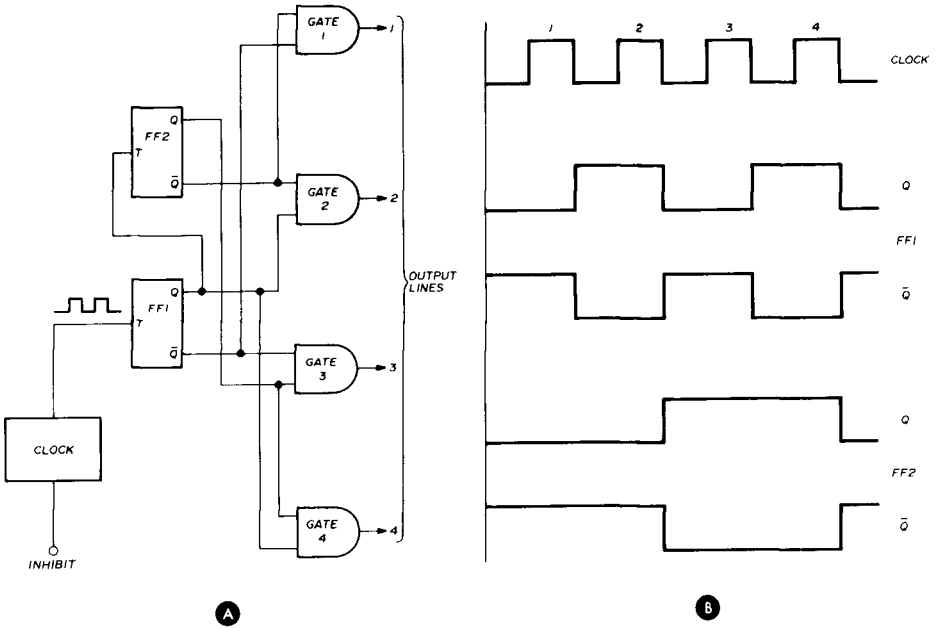



**fig. 4. Logic diagram of a four-channel decoder using one dual J-K flip-flop IC and one quad two-gate (A). Waveform diagram showing design rationale for the four channel scanner is shown in (B).**

Q1, operates as a pulse-generator clock. This circuit supplies sawtooth pulses to the pulse-shaping and control circuit. In that section the pulses are changed so that the counter circuits to follow see the abruptly changing waveforms they like.

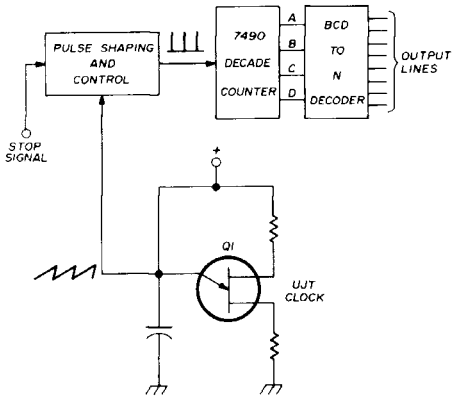



**fig. 3. Partial schematic of the scanning logic of a typical receiver. In this design the BCD lines from the counter are decoded into N distinct output lines where N is the number of channels. The easy availability of IC octal and decimal decoders make eight- and ten-channel designs especially appealing.**

The control portion of the circuit interrupts, on command, the flow of pulses to the SN7490 decade counter.

The Binary Coded Decimal (BCD) output from the counter is fed to a decoder which selects one of several output lines each time an input pulse is received. Examples can be found where the decoder is a suitable connection of NOR/NAND gates or an octal or decimal decoder IC such as found in decimal counting units.

The simple four-channel scanner in **fig. 4A** uses two J-K flip-flops (which are usually housed on the same IC chip) and four two-input gates (also usually a single IC). This circuit sequentially selects from among a bank of four crystals.

Waveforms which explain the operation of this circuit are shown in **fig. 4B**. The NAND gates are wired to the flip-flops in such a way that they produce a grounded output (logic zero) only when *both* inputs are high (logic 1). Notice the waveforms from FF1 and FF2 underneath clock pulse number 1. At this time only the $\overline{Q}$ of FF1 and the $\overline{Q}$ of FF2 are

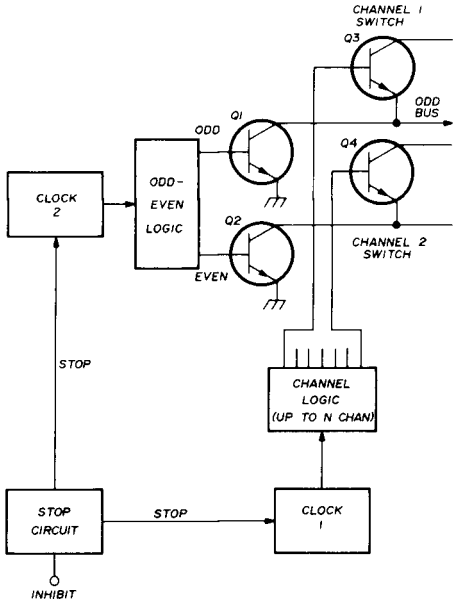



**fig. 5. A simple four-channel scanner can be made to scan twice as many channels with only the added complexity of an odd-even selector. In this case the normal scan logic is the same for both channels—which is selected during any given interation of the logic signal is determined by the odd-even flip-flop.**

high so they are used to drive gate 1. When clock pulse 2 arrives the Q output of FF1 and the $\overline{Q}$ of FF2 are high while all others are low. They are used to drive gate 2. This sequence continues through all four pulses from the clock, then repeats.

Most scanner receivers offer more than four channels. In fact, the standard seems to be eight. Since the binary system is based on powers of two it might be imagined that a mere doubling of the circuit of **fig. 4** would suffice. In actuality, however, the gating of eight channels is a bit more complex.

A few receivers simultaneously scan two four-channel crystal banks which are designated *odd* and *even*. One additional flip-flop sequentially selects from these two alternate banks. An example of the odd-even select system is shown in **fig. 5.**

## crystal switching

Transistor Q1 in **fig. 6** is the regular vhf overtone crystal oscillator used to drive the first mixer. Although the circuitry for only one channel is shown here, assume that each channel will have a similar arrangement. The cold end of the crystal, Y1, is grounded through transistor Q2 when Q2 is turned on by command from the logic circuit.

When the logic circuit selects the channel a positive voltage is applied to the base of the appropriate switching transistor. This saturates the transistor, causing a collector-emitter resistance of only a few ohms. Under this condition diode CR1 is forward biased (allowing the crystal to be grounded) and the light-emitting diode, CR2, finds a current path to ground. Depending upon design you will sometimes find lock-in or lock-out switches which will either manually select a channel or prevent it from being energized. Most scanners incorporate a small trimmer capacitor to net the crystal on their respective channels.

## crystal selection

As some of us have discovered the hard way, crystals are neither absolutely calibrated (despite case markings) nor do they necessarily remain on frequency once in a circuit. The exact frequency of operation depends upon both the ambient temperature and the circuit parameters. It is, therefore, necessary to state precisely your requirements when ordering from a crystal or scanner manufac-

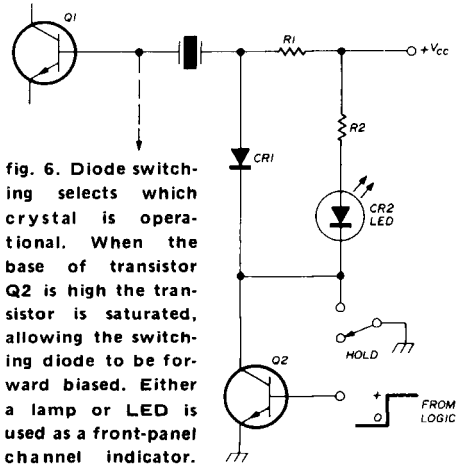



**fig. 6. Diode switching selects which crystal is operational. When the base of transistor Q2 is high the transistor is saturated, allowing the switching diode to be forward biased. Either a lamp or LED is used as a front-panel channel indicator.**

turer. It isn't like the old days of 40-meter CW where you bought a crystal ±2 kHz.

Crystals for any given scanner can usually be purchased from the respective dealers or from a crystal manufacturer. Before you order, especially from a crystal manufacturer, you will need certain facts about the required crystal. One piece of data, of course, is the operating frequency. To find this you must know both the channel frequency and the i-f of your unit. You also need to know whether crystal operation is in a fundamental or one of several overtone modes.

*Vhf-fm scanners typically (but not* universally) operate in the fundamental mode on low band (30-50 MHz), the third overtone on high band (148-174 MHz) and the ninth overtone on uhf. Assuming this to be true in your own receiver, use one of the following formulas for determining crystal frequency:

**Low band (including 6 meters):**

Crystal frequency = Channel frequency + i-f

**High band (including 2 meters):**

$$\text{Crystal frequency} = \frac{\text{Channel frequency} + \text{i-f}}{3}$$

**uhf:**

$$\text{Crystal frequency} = \frac{\text{Channel frequency} + \text{i-f}}{9}$$

Note that in some receivers the manufacturer will specify that you are to *subtract* the i-f from the channel frequency.

Prepare a simple chart for the crystal supplier listing the following:

1. Make and model of receiver.
2. Crystal frequency desired.
3. Holder style (consult catalog).
4. Mode of operation (fundamental, third overtone, etc.).
5. Circuit capacitance.
6. Drive level in milliwatts.
7. *Maximum allowable series resistance.*
8. Temperature (if in oven).

This information can usually be found in the service manual for your receiver. If a manual is not available consult Howard Sams' *Scanner-Monitor Service Data.** *This handbook covers most of the more* popular types of scanner receivers.

It is worth noting that the cost of crystals can almost double the cost of the scanner if you don't shop around a little. It is often advisable to buy a unit custom set-up from the factory with all crystals *in place. This is generally less expensive* and is also more likely to result in satisfactory performance should your local dealer be unable to provide good quality alignment service.

## other scanner-receiver circuitry

For the most part the remaining

**Scanner-Monitor Servicing Data,* Volume 1, SD-1, 1972, and Volume 2, SD-2, 1973, Howard W. Sams and Co., Inc., $4.95 each from Ham Radio Books, Greenville, New Hampshire 03048. Volume 1 covers the **B&K** PF-1; **Browning** XM-888; **Johnson** Duo-Scan Low Range, High Range, 241-0340-001, and 241-0340-002; **Midland** 13-915 and 13-925H/L/M; **Pace** Scan 108H/L/U, 280 and 308; **Pearce-Simpson** Gladding Hi-Skan; **Penneys** 981-6065, 981-6066 and 981-6067; **Realistic** Patrolman Pro-7 (20-5001), Patrolman Pro-8 (20-162) and Patrolman Pro-9 (20-164); **Sonar** FR-104, FR-105, FR-2516, FR-2517, FR-2525, FR-2526 and FR-2528; and **Teaberry** Scan "T". Volume 2 covers **Electra** Bearcat III; **Midland** 13-922 and 13-927; **Regency** R1HT1-1, R1LT1-1, R1UT1-1, R2HT1-1, R2LT1-1, R2UT1-1, TME-16U, TMR-1U and TMR-8U; **Tennelec** Tennetrac I/II/IV; and **Unimetrics** Digi-Scan 4+4 and Digi-Scan-8.

Also available is *Scanner-Monitor Data,* Volume III, SD-3, 1974, $5.95 from Ham Radio Books. This volume includes schematics, *parts lists and service adjustments for the* following scanner receivers: **Electra** Jolly Roger; **Johnson** Hi/Lo Duo-Scan, UHF/VHF Duo-Scan (late production), UHF Mono-Scan and VHF Mono-Scan; **Midland** 13-914; **Pearce-Simpson** Cherokee 8+8, Cheyenne 8 (PR-78) and Comanche 16 (PR-160); **Regency** MT-15S, TME-16H/L, TME-16H/LH/U, TME-16H/LL/U, TME-16H/LM/U, TMR-1H, TMR-1L, TMR-4H, TMR-4L, TMR-8H, TMR-8L, TMR-8H/LH, TMR-8H/LL and TMR-8H/LM.

circuits found in scanner receivers will closely parallel similar circuitry in other vhf-fm receivers including quite a few two-meter fm transceivers.

The second mixer of one popular scanner receiver is shown in **fig. 7**. Input signals to the mixer are coupled through a tank circuit and a ceramic crystal bandpass filter. The output of the mixer is tuned to the lower i-f by another, similar crystal filter.

Since most commercial transmitters use narrowband fm (±5-kHz deviation) a 12- to 16-kHz passband is required. This allows the use of many low-cost ceramic filters such as the Murata line from Japan. These same filters in different bandwidths are used in many home and auto fm and fm-stereo broadcast radios.

I-f amplification is almost universally supplied by a one- or two-stage IC amplifier. The detector might be an ordinary diode type or it might be an IC. Some scanners use the standard ratio detector/discriminator circuits which feature i-f amplification, limiting and detector diodes in one IC package. An example is the RCA CA3043. Others use an IC quadrature detector such as the Motorola MC1357.

An unusual squelch circuit is shown in **fig. 8**. This design uses switching diodes to generate squelch action. This circuit produces little audio distortion because low-level ac (i.e., audio) signals can ride on top of high levels of dc which forward biases the diode. The circuit operates by causing the transistor to saturate. When that occurs the B+ to the diodes is shunted to ground, causing the diodes to be reverse biased. This cuts off the audio path. When the transistor is inoperative again the B+ biases the diodes to pass audio signals.

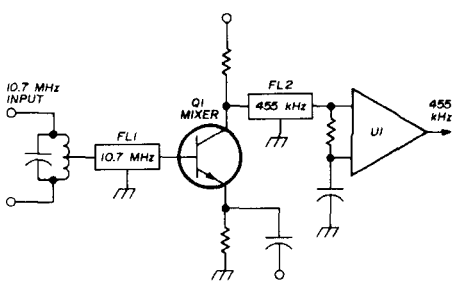



**fig. 7. Most modern vhf-fm scanner receivers use modern design for the i-f strip and second mixer. This circuit uses ceramic bandpass crystal filters and an IC amplifier, U1.**

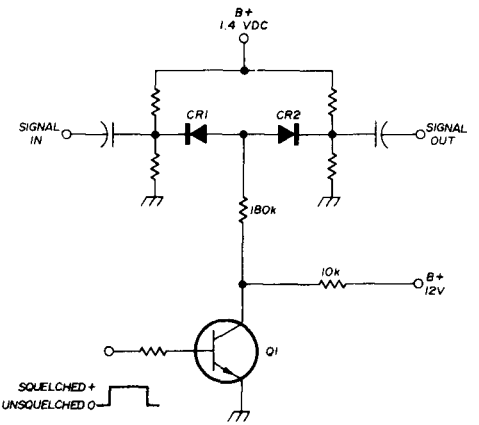



**fig. 8. Diode switching is also useful in squelch circuits. When transistor Q1 is cut off B+ flows through the 10k and 180k resistors, forward biasing the switching diodes, allowing low-level audio signals to pass through. When the transistor is saturated, however, the B+ to the diodes is shunted to ground and they are effectively reverse biased.**

## future of scanners

The scanner market will undoubtedly be soon overrun with lower cost import and domestic models. Many of these receivers will require modification, even to the extent of completely changing the front-end tank circuits to a new range, before they can be used on the amateur bands. Others either already have sufficient range or will be available in amateur band models. In either event expect to see more amateur use of these receivers. They allow you to monitor several active frequencies or repeaters at one time. Perhaps the next logical extention of this concept is to make a transmitter in the same box which also scans. The combination could then be set to keep tabs on *all* local activity.

**ham radio**

# integrated-circuit ssb transceiver

Complete construction details for a miniature ssb transmitter and receiver using Plessey ICs

Brian D. Comer, G3ZVC, Senior Applications Engineer, Plessey Semiconductors

**This article describes** the i-f and audio circuitry of a single-sideband transceiver designed by the Applications Department of Plessey Semiconductors using their SL600-series integrated circuits. The transceiver may be used at any frequency from a few kHz to 500 MHz.

The unit described in this article consists of a single printed-circuit board which requires only the addition of a local oscillator, a preselector, a linear amplifier, volume control, microphone and loudspeaker to build a complete transceiver.

## receiver

The receiver is a single-conversion superhet with a 9-MHz i-f. To optimize its intermodulation performance the incoming signal is fed directly to a hot-carrier diode ring mixer and then to the crystal filter; there is no rf amplifier. The i-f sensitivity is such that at frequencies of 30 MHz or less no rf amplification is required if a reasonable antenna is used (as it would be with a transceiver). However, if the receiver is used at frequencies above 30 MHz, or with a less than ideal antenna, some rf gain may be necessary to obtain the necessary noise figure. The rf amplifier should have the lowest gain consistant with the frequency and antenna to be used and must have good large-signal handling capability if receiver performance is not to be degraded.

The mixer is an Anzac MD108 hot-carrier diode double-balanced modulator.* This device was chosen for its conveniently small size, high performance and low cost, but similar devices from other manufacturers could also be used. All the ports of this modulator are designed for 50 ohms; two have a frequency range of 5 to 500 MHz while the third covers the frequency range from dc to 500 MHz. The input from the antenna is applied to the dc- to 500-MHz port via a preselector, and the local oscillator—at a level of +7 dBm (500 mV rms)— is applied at pin 8 (see **fig. 1**). The mixer output from the rf port passes through a toroidal transformer to match it to the 500-ohm input impedance of the crystal filter. If other types of filters are used it may be necessary to re-design the impedance-matching transformer.

Once the signal has passed through the

*Anzac MD-108 double-balanced mixers are available in small quantities from Anzac Electronics, 39 Green Street, Waltham, Massachusetts 02154. The price is $7.00 each, plus postage.

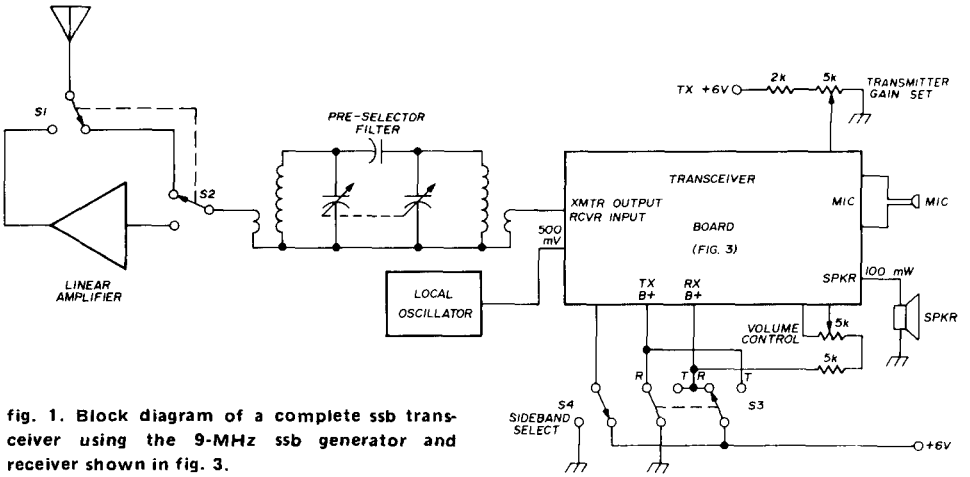



**fig. 1. Block diagram of a complete ssb transceiver using the 9-MHz ssb generator and receiver shown in fig. 3.**

crystal filter, a 2.4-kHz bandwidth 9-MHz filter with 90-dB stopband suppression, there is little further risk of cross-modulation or intermodulation. The i-f strip consists of three cascaded Plessey SL612C* i-f amplifiers followed by an SL640C product detector. Without agc applied each SL612C has 34-dB gain and 15 MHz bandwidth. Since a broadband i-f strip consisting of three SL612Cs has more than 100-dB gain and 15 MHz bandwidth, it can very easily become unstable. Therefore, the circuit board layout is very important (see **fig. 4**). It is relatively easy to build a three-stage, broadband i-f strip on double-sided printed-circuit board if the component side has a plane of grounded copper, but on single-sided board the layout shown in **fig. 4** should be rigidly adhered to.

The beat-frequency oscillator for the product detector uses an fet circuit that delivers about 100 mV rms to the SL640C product detector. This oscillator also supplies the carrier for the transmitter balanced modulator. One of two crystals, for upper or lower sideband, is selected by a diode switching arrangement.

The detected audio from the product detector drives an SL630C audio output stage which is capable of providing about 65 mW to headphones or a small loudspeaker. The detected audio also drives an SL621C agc system. Since the SL630C has voltage-controlled gain, the volume control consists of a potentiometer which provides a control voltage to the SL630C. If 65 mW is insufficient output (it is worth listening to it before deciding as it is usually adequate for domestic listening) an external, higher power audio amplifier may be driven either from the SL630C output or directly from the product detector.

The agc is provided by an SL621C audio-derived agc system. Its output is buffered by a transistor Q2 so an S-meter may be connected if desired. Since Q2 reduces the available agc voltage swing,

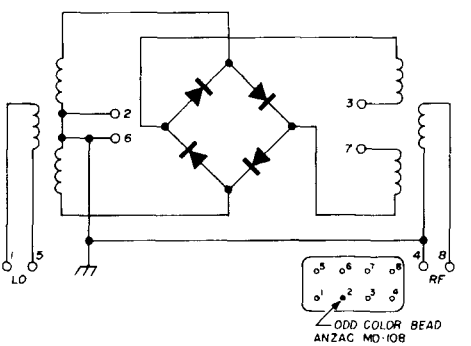



**fig. 2. Schematic diagram of the Anzac MD-108 double-balanced diode mixer. Local-oscillator signal is applied to pins 1 and 5, input (output) preselector circuit is connected to pins 3 and 7, and transformer T2 is connected to pin 8.**

*Plessey integrated circuits are available from Plessey Semiconductors, 1674 McGaw Avenue, Santa Ana, California 92705.

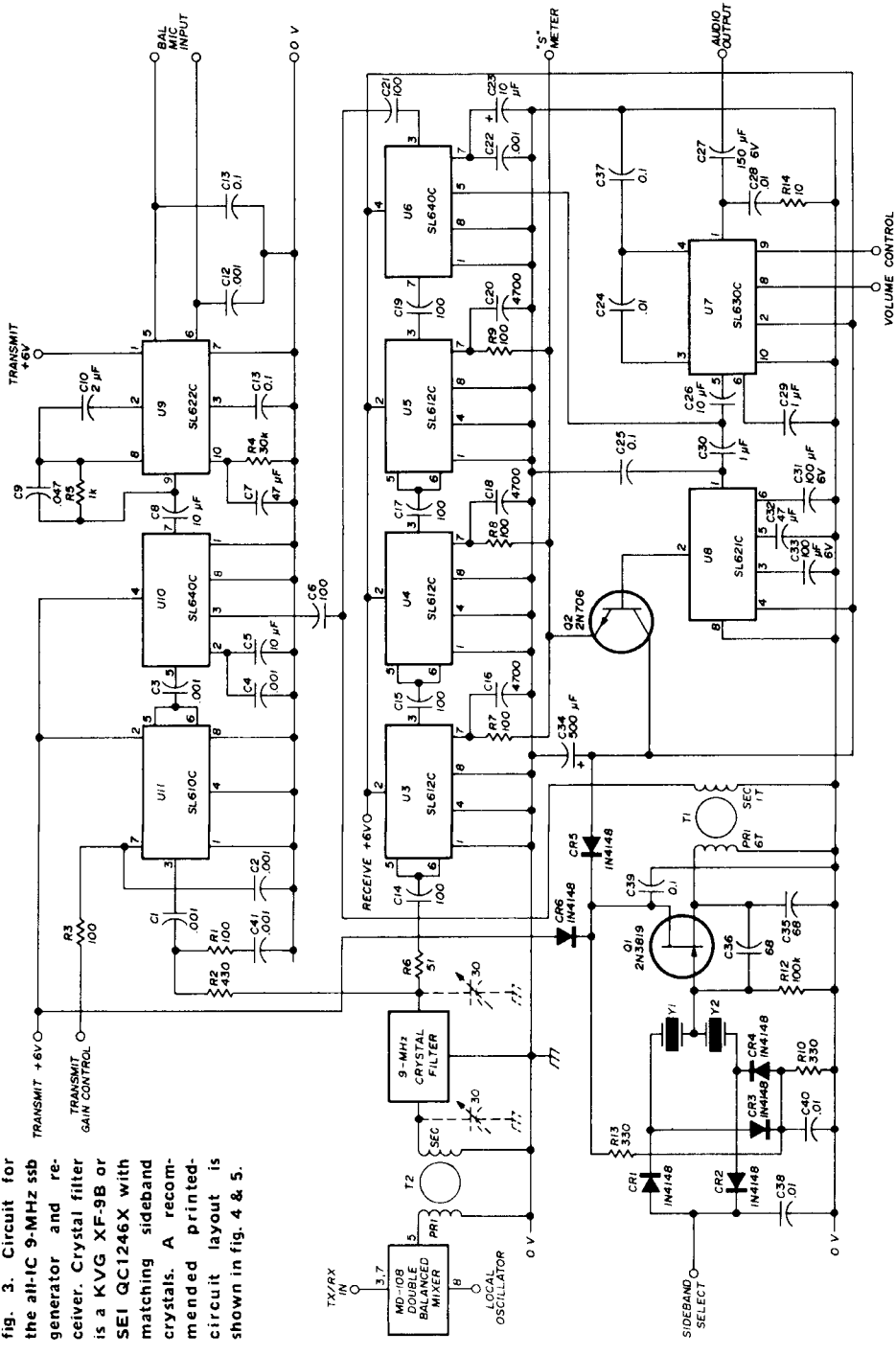



fig. 3. Circuit for the all-IC 9-MHz ssb generator and receiver. Crystal filter is a KVG XF-9B or SEI QC1246X with matching sideband crystals. A recommended printed-circuit layout is shown in fig. 4 & 5.

agc is applied to all three i-f stages to ensure that the agc can cope with the receiver's 112-dB dynamic range. If resistor R7 is replaced by a germanium diode there will be a delay to the first-stage agc—this may improve receiver noise figure very slightly on small signals—and is barely worthwhile. Capacitors C16, C18 and C20 are kept down transmitter/receiver side of the crystal filter on the change-over from receive to transmit. All the transmit/receive switching on the board is achieved by turning on the appropriate power line (transmit or receive) and grounding the unused line. The grounding of the unused line is very important as instability can result if it is not done.

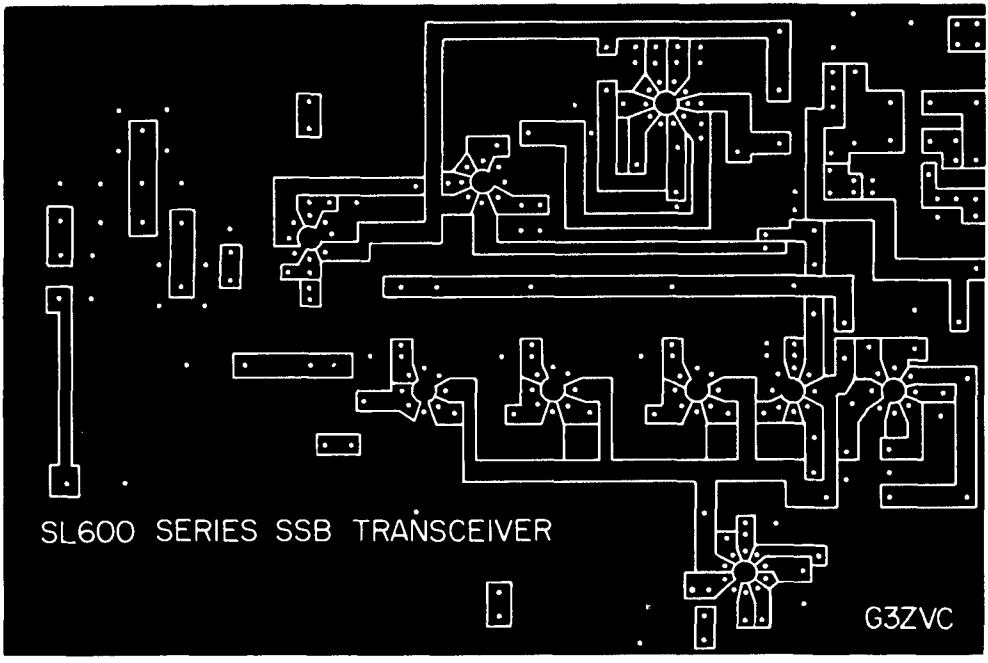



**fig. 4. Full-size printed circuit layout for the 9-MHz ssb transmitter and receiver. Component layout is shown in fig. 5.**

to 4700 pF to retain the ignition suppression characteristics of the system.

## transmitter

The transmitter is also a single-conversion design. It generates a 9-MHz single-sideband signal using the same crystal filter as the receiver. The 9-MHz ssb is converted to the final operating frequency by the MD108 ring mixer; the unwanted frequency product is removed by the preselector. This system requires no signal switching between the antenna side of the preselector and the

The audio input from the microphone is amplified by an SL622C agc amplifier which will give a constant 100-mV rms output for a 60-dB input range. If a single-ended input is used rather than a balanced input, dynamic range is reduced to about 46 dB. In most systems 60 dB input dynamic range is too large, 40 dB being sufficient, so resistor R5 has been included in the circuit. If 60 dB dynamic range is required resistor R5 should be omitted and C9 reduced to 4700 pF.

The audio output from the SL622C

microphone amplifier goes to the SL640C double-balanced modulator. The carrier input to the balanced modulator is fed by the bfo (which works on both transmit and receive since its power may be derived from either line through diodes CR5 and CR6). The output from the impedance-matching transformer and is mixed with the local oscillator signal to provide the final transmitter frequency (and an image which is removed by the preselector). This is amplified by the linear amplifier and transmitted. The output from the preselector is about 70 mV rms.

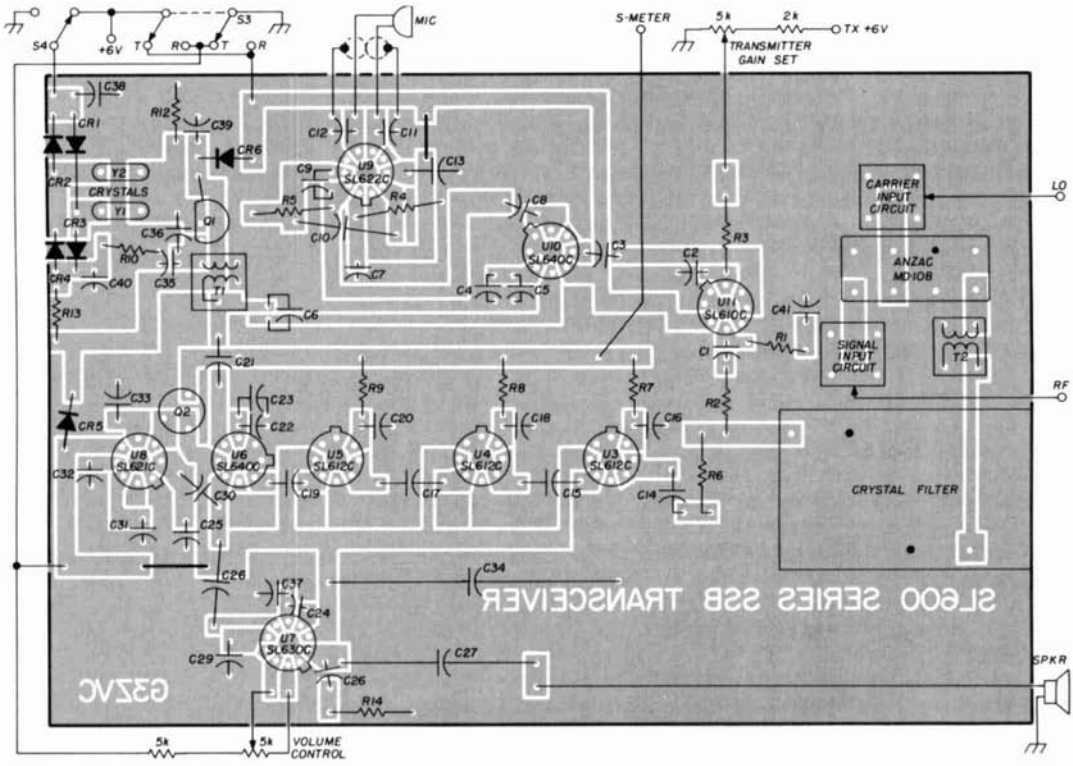



**fig. 5. Component layout for the 9-MHz ssb transmitter and receiver. Space is provided for installing the input circuits for the local oscillator and signal. Design of these circuits depends upon the frequencies selected for your own application.**

SL640C is a double-sideband signal with low carrier feedthrough (usually -40 dB) which is amplified by an SL610C. The gain of this particular device may be controlled either by an alc signal, derived from the transmitter linear amplifier or manually with a dc gain control. The amplified dsb signal is sent through the crystal filter to remove one sideband. Resistors R1 and R2 ensure a correct match to the crystal filter both on transmit and receive.*

The ssb output from the filter passes to the doubly-balanced diode mixer via the

## construction

The complete system is built on a single-sided printed-circuit board that requires two jumpers—one in the receive supply, the other in the transmit supply. If only a receiver is required, components

*A 30-pF (nominal) capacitor from the input pin to ground will improve the passband ripple and a 20-pF capacitor from the output pin to ground will do the same. In practice, however, it has been found that these components make little difference (1-dB additional passband ripple). The KVG XF9B is the same as the SEI QC1246AX.

R1 to R5 inclusive, C1 to C13 inclusive, C10, and the semiconductors U9, U10, U11, CR5 and CR6 must be omitted, a wire jumper connected where CR5 was, and a 500-ohm resistor connected from the filter end of R6 to ground.

The layout of the board is quite critical and changes of printed-circuit design will almost certainly lead to instability unless double-sided board is used. The design shown may be built on double-sided board quite safely.

The components used in the original unit are given in the schematic. Bead tantalum capacitors are used where possible for their small size but since they are sometimes hard to find in high capacitances at high voltages, aluminum electrolytics have been specified in three places. The WeeCon capacitors specified may be replaced with other miniature high-K ceramic capacitors but the values of components should not be changed. The resistors are all 1/8-watt, 10% types.

Transformer T2 is made on a ITT CR-071-8A toroid core (the Amidon T-37-2 is a suitable substitute). Four 2-inch (5-cm) lengths of number-26 wire are twisted together and two turns are wound on the core with the twisted wire. The ends are then opened and three windings are connected in series for the filter winding and the fourth is used as the winding connected to the diode ring. Transformer T1 is wound on a core of the same type and has a 6-turn primary and a single turn secondary.

This ssb transceiver is probably the simplest which may be made using the Plessey SL600 series ICs, but its performance is not compromised in any way. It has a sensitivity of better than 0.5$\mu$V for 10-dB signal-to-noise ratio, it can handle signals of over 200 mV rms at the diode mixer with minimal intermodulation distortion, and the board uses less than 500 mW on transmit or receive. It has been designed so that anyone with basic technical competence but without previous experience in ssb transceiver design can build a successful ssb transceiver.

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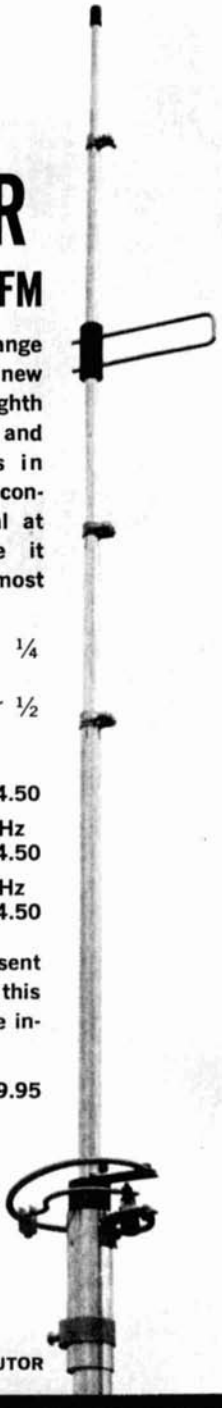

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# harmonic phase detector

Circuit description of a simple harmonic phase detector that requires input signals to have a 2:1 frequency relationship

Henry S. Keen, W5TRS, Fox, Arkansas 72051

**The phase lock loop** has found many applications in modern electronics. One of the more important, to radio amateurs, is in the detection of fm signals where a voltage-controlled oscillator or vco is maintained at zero beat with the incoming fm signal. The control voltage generated for this application by a phase detector becomes the audio-frequency output signal. Suitable integrated circuits for this purpose are becoming available, and offer much convenience to the builder.

However, a problem in design and layout may appear wherein the vco signal may leak into a high-gain i-f system, possibly even causing saturation. An answer to this situation is the harmonic phase detector shown in **fig. 1**. This phase detector requires that the local vco operate at twice the intermediate frequency of the receiver. As a matter of fact, it won't even work if the two input signals are the same frequency! The circuit can be seen to represent a pair of peak-reading diode detectors of opposing polarity, with differential output.

The action of this circuit is illustrated in **figs. 2** and **3**. In **fig. 2**, where both signals cross the zero axis simultaneously, the positive and negative peaks of the

difference between the two input signals will be equal. Under these conditions the differential output signal will, of course, be zero. In **fig. 3**, however, when a phase difference exists between the cross-over points of the two input signals, this equality no longer exists, and a differential output voltage will be produced. The magnitude and polarity of the resultant output will be a function of the degree and direction of the phase difference.

In common with the reciprocating detector[1] this circuit was also devised to receive double-sideband suppressed-carrier signals as I am especially interested in the potential advantages of portable and mobile equipment in which the entire input to the final amplifier might be in the form of audio frequency power, obtained from a transistor amplifier, operating directly from the car battery.

By referring to **fig. 3** it can be seen that polarity reversal of the lower frequency, representing the double-sideband signal, will merely interchange the relative positions of the two peaks of either polarity. This change can have no effect upon the polarity or amplitude of the differential output.

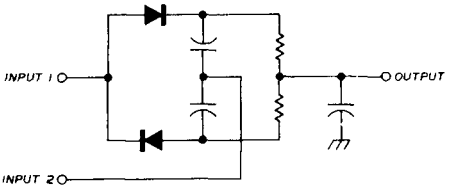


**fig. 1. In this simple harmonic phase detector the two input signals must have a 2:1 frequency relationship. Applications include phase-locked loops and double-sideband signal reception.**

A possibly over-simplified explanation would be to say that the 180° phase shift, inherent with the double-sideband signal, when compared with twice its frequency, is equivalent to a phase shift of 360°,

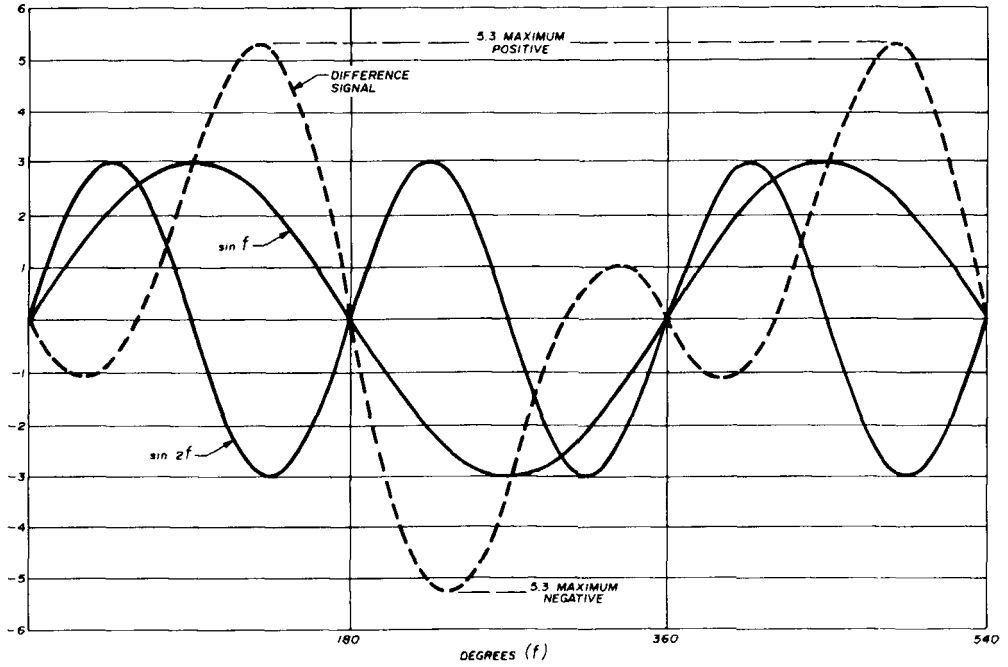


**fig. 2. Operation of the harmonic phase detector with zero phase difference between equal signals at frequencies f and 2f. Differential output is zero.**

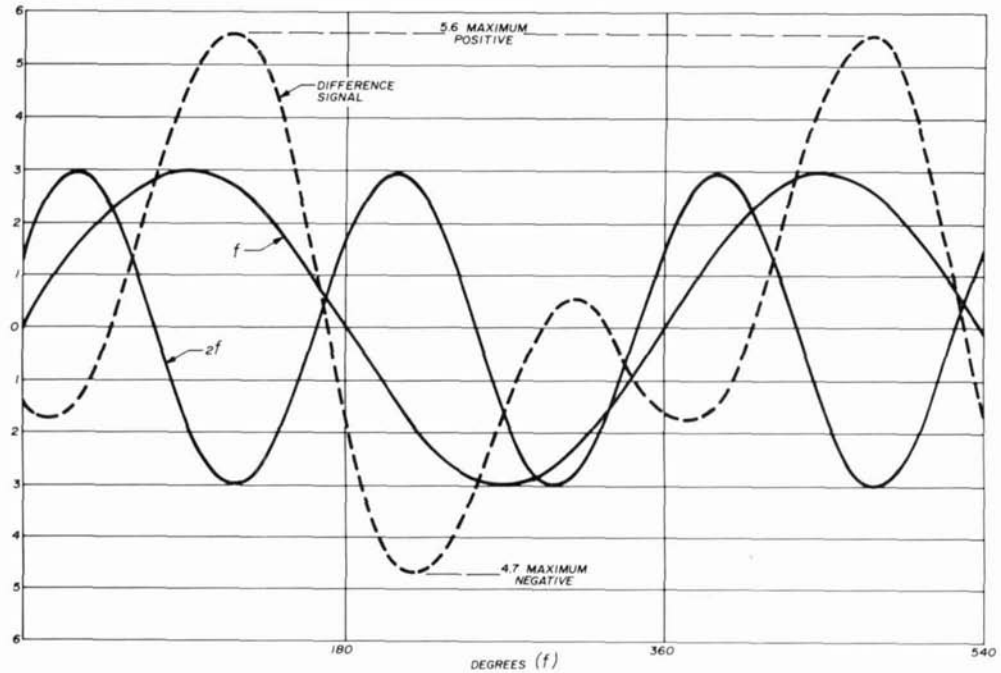


**fig. 3. Operation of the harmonic phase detector showing effect of phase shift between signals at frequencies f and 2f. Differential output voltage is produced.**

which is no phase shift at all! Suitable hard limiting of the double-sideband signal before its application to the phase detector, followed by suitable integration of the detector's output pulses permitted the necessary phase lock for double-sideband reception, but that's another story.

By grounding one of the two inputs (because the inputs are essentially in series) the detector may be made to function as an indicator of the most common form of second harmonic distortion of an audio-frequency signal, where limiting of either the positive or negative peaks is present. This fact suggests that the harmonic content of the human voice might conceivably be sufficient to lock the tuning of a ssb receiver with the aid of suitable filtering.

This simple circuit appears to have many possible applications which the amateur experimenter might find useful, and this article is prepared with that hope in mind.

**"I wish you would learn to control your temper, and not try to punch everyone who says something you don't like."**

**reference**

1. Stirling Olberg, W1SNN, "Reciprocating Detector," *ham radio*, March, 1972, page 32.

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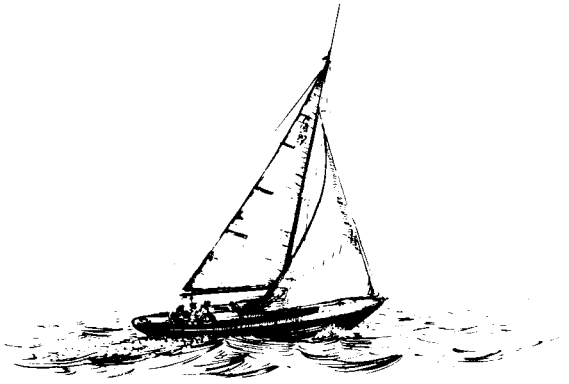

# amateur marine installations — small boat style

Overcoming the practical problems and legal restrictions of hamming from a pleasure boat

R.P. Haviland, W3MR, 136 Brownlie Road, King of Prussia, Pennsylvania 19406

**Amateur radio station** installations on private yachts of various sizes is increasing at a rapid rate. Operating a ham station on your boat is a nice way to combine your hobbies. However, it is also a hobby combination which has special requirements, both legal and practical. Let's discuss some of these special requirements, based on my personal experience as well as on observations of shipboard installations by other amateurs.

## grounds

The radio ground system on a boat has three functions: rf grounding, lightning protection and corrosion prevention. For rf the rule is very simple—the larger the ground area, the lower the ground resistance and the greater the antenna efficiency. If it is large enough, the ground does not have to be in physical contact with the water—it can serve as one plate of a low-reactance series capacitor, with the water serving as the other plate.

The safest rule to follow for a lightning ground is to have lots of ground area in direct contact with the water, and a good direct-contact rf ground would also be a good ground for lightning. The lead wire should be large—at least number-10, and preferably larger. The radio and

lightning grounds can be kept separate, either by using a lightning arrestor or by having a heavy knife switch which grounds the antenna when it is not in use. One commonly used method is to make up a lead with a heavy clip on one end and a length of bare wire or a zinc electrode on the other, fastening the clip to the antenna and dropping the electrode end over the side during storms or when the boat is not in use.

There are two factors that must be considered in anti-corrosion protection. These are corrosion due to dissimilar metals, and corrosion from stray current flow. On most boats the regular anti-corrosion measures—zinc electrodes, plus cathodic protection on metal hulls—will also take care of any stray currents resulting from the radio installation. However, a good precaution is to replace the original power switches in the radio with a type which opens both sides of the supply, completely isolating the radio from the power source when it is turned off. It is also a very good idea to inspect all underwater metal on your boat a few weeks after making any new installation or change, to detect any problem before major damage occurs.

One very successful water contact ground is made from two copper tubes, typically 3/4- to 1-inch (1.9- to 2.5-cm) in diameter and 10-feet (3-meters) long, one mounted on each side of the keel. A variation of this uses a copper sheet, 3- to 4-inches (7.6- to 10-cm) wide by 10-feet (3-meters) long, tacked to the side of the keel or to the bottom of the boat. Both are good. On sailboats, the ground connection is often made to the bolts holding the lead keel. This seems to be satisfactory, but the ground lead should be connected to a number of the keel bolts to provide the lowest contact resistance.

On fiberglass boats a good non-contact or capacitance ground can be made by attaching 10 square feet (about one square meter) or more of light copper screen or perforated mesh to the hull below the waterline, using resin as the adhesive. This should also be satisfactory with wood boats, but I have never seen it so used. Some fiberglass sailboats carry the lead ballast inside the hull, as a casting set into the keel, and this can be used as a capacitance ground. All of these non-contact rf grounds should be supplemented by a lightning ground: I have seen an internal keel sailboat which was struck by lightning in which the charge escaped to the water by punching a number of small holes through the fiberglass at the upper edge of the keel casting.

The ground system of the sailboat on which I operate W3MR/M is a combination type. All shroud chainplates are connected by number-8 aluminum wire, a total of about 50 feet (15 meters). This makes a fairly good capacitance ground. In addition, two standard zinc teardrops on the outside of the hull are connected to this bus, further reducing the ground resistance, and giving lightning and corrosion protection. These zinc teardrops require replacement on occasion, showing that there is some current flow.

## antennas

On many boats the mounting of an amateur antenna is complicated by the fact that the best antenna mounting place has been preempted by a marine radio installation. If a marine radio installation is already aboard, or one is contemplated, it should be remembered that the amateur station must be completely independent of and must not interfere with the marine installation. Compromises of the amateur antenna system, several trial installations, use of bandpass filters and the like, may be necessary.

Any of the mobile-whip or loaded-whip antennas can be used on a boat if one factor is considered. This is the extra lead length to ground, usually on the order of feet on a boat instead of inches as on an automobile. As a result, fixed-tuned loading coils will usually resonate outside the band. One solution is to use the loading coil for the next higher frequency band. Since the antenna is

actually being fed above ground, it has higher than normal impedance plus reactance. Even with adjustable loading coils, a matchbox is a good idea.

Some good mounting places for amateur-band whip antennas are: at the upper edge of the pilot house on the side away from the marine antenna; at the rail, usually on the stern quarter; at the masthead; or strapped to the mast, if it is wood. Try to keep a minimum of several feet of separation between the antenna and rigging, and as far apart as possible from other antennas.

Boats with masts can use wire antennas. On a power boat an antenna from the bow to a midships mast to the stern flagpole is good; feed can be at any convenient point, using a matchbox. On sailboats a standard installation is to insert large compression insulators at the top and bottom of the backstay, feeding it from the bottom end. Two-masted boats can have an antenna hung between the masts. My installation does this, using three separate lengths of wire cut for 10, 15 and 20 meters and operated as monopoles. The feedline coax shield is connected to the shrouds, which are grounded as noted above. In comparison tests with several other trial antennas this arrangement consistently gave the best results.

It is not really necessary to insulate rigging or wire to use it as an antenna. The objective is to get rf current flowing in a conductor that acts like an antenna. For example, on a typical medium-size sailboat the mast will be a 32- to 40-foot (about 10- to 12-meter) length of aluminum, a good approximation of a half-wave on 20 and a quarter-wave on 40. There are several ways to induce rf current flow. Some common ones are: feed the bottom end directly, if it is insulated (used on my boat on 40 and 80); use one of the shrouds as a gamma match; run a piece of insulated wire several feet (one meter) up the mast, again as a gamma match; or form the running-light leads (when present) into a coil, using this as part of a matching network. The key to success in the use of one of these methods is a good antenna tuner (see later)— and patience in making trials.

Beam antennas are rarely seen on small boats—they are too complicated and bulky, and not worth the trouble. If you want to try using a beam there are several short-element designs on the market, and a number have been described in various handbooks. Loading coils can be used to bring a TV antenna into resonance on 6 or 10 meters, although the bandwidth will be narrow. Another possibility is an array of three or four whip antennas, say on the wheelhouse or even on the quarters.

Still another possibility is a shore antenna. For temporary use a trap vertical lashed to a dock piling is good, though it may have to be retuned as the tide changes. It is often possible to use a long-wire antenna, end fed from an antenna tuner, and run as far as possible in the general direction of preferred signals. At the ship's home port a permanent rotary beam installation may be possible.

## matching

If antennas other than trap verticals are used, it is a good bet that the antenna tuner will have to handle some unusual feed impedances. This eliminates use of some of the standard designs, which are intended for a limited range of loads and relatively low reactance.

After a number of trials I settled on a homebrew antenna tuner that is a modification of an ARRL Handbook design of some years ago. One or another of its switch settings will permit matching any impedance over the range from 3 to 30 MHz; the last position grounds the antenna. The tuner described in the May, 1974, issue of *ham radio* would be a good one for this application.[1] Because of the many possibilities, adjustment of the tuner can be tedious. It seems to be a good idea to try a pi configuration first. If this does not give a satisfactory match, try the low-impedance positions for loop-fed antennas, and high-impedance

settings for other types. Several configurations and settings of your tuner may give a match; use the one which is least critical to a change in frequency.

In addition to matching, an antenna tuner also helps keep the chassis of the transmitter at rf ground. Sometimes it will still be necessary to add filtering to the mike and key leads, and to set up special grounds for the transmitter chassis.

## operating convenience

Because of space limitations, it is very difficult to get an operating position on a boat which is really convenient. The best I have seen was on a fair sized sailboat, where the place called "navigators area" on the ship's plans had been rebuilt into a radio area. Since this boat was used only in inland waters, the loss of navigational convenience could be accepted.

A suggestion—make a temporary installation, and use it long enough to find the type of operating you prefer—tied up or underway, phone or CW, net or casual, and so on. Then work out a convenient position for this type of operation. If you like net or favorite frequency operation, don't forget the possibilities of crystal control and a remote operating position.

## legal matters

There seems to be considerable confusion about the proper identification when operating aboard a boat. The following are the tests I use:

If underway, operation is obviously *mobile*.

If at anchor or tied up, and the ship can get underway without interrupting a contact, operation is still *mobile*.

If some shore-side facilities are being used, and operation would have to be interrupted to get underway, operation is *portable* rather than mobile (typically when shore power or a shore-side antenna are used).

If the ship's location is in waters bearing the chart notation, "Use International Rules of the Road," the designator is still *mobile* followed by the ITU Region, rather than a location and/or call area. The Americas are in Region 2. Note that operation in coastal waters of another country requires permission of that country.

For the record, here is what the FCC says about your operation from shipboard:

**97.101 *Mobile stations aboard ships or aircraft.***

In addition to complying with all other applicable rules, an amateur mobile station operated on board a ship or aircraft must comply with all of the following special conditions: (a) The installation and operation of the amateur mobile station shall be approved by the master of the ship or captain of the aircraft; (b) The amateur mobile station shall be separate from and independent of all other radio equipment, if any, installed on board the same ship or aircraft; (c) The electrical installation of the amateur mobile station shall be in accord with the rules applicable to ships or aircraft as promulgated by the appropriate government agency; (d) The operation of the amateur mobile station shall not interfere with the efficient operation of any other radio equipment installed on board the same ship or aircraft; and (e) The amateur mobile station and its associated equipment, either in itself or in its method of operation, shall not constitute a hazard to the safety of life or property.

Hamming from your boat can not only be a lot of fun, it can also enhance your boating safety by providing a much-needed communications link in time of trouble. Like any amateur installation in less than ideal circumstances, the typical shipboard ham station will be limited in both operating convenience and efficiency—but that won't keep any enthusiastic boater/ham off the air. Just listen for W3MR/M on all bands.

### reference

1. Harry R. Hyder, W7IV, "Five-To-One Transmatch," *ham radio*, May, 1974, page 54.

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# electronic speed control for RTTY machines

## Single-knob RTTY speed control permits instant speed change

K.H. Sueker, W3VF, 110 Garlow Drive, Pittsburgh, Pennsylvania 15235

**In a rash moment** I decided to invest in a governor-motor Kleinschmidt TT271 KSR page printer to use for high speed operation. The prospect of 60 to 100 wpm operation for $40 was just too good to pass up. Much to my pleasant surprise, the governor worked perfectly and the machine generated no rf interference in my receiver. With 100 wpm gears and various governor adjustments it would run from 67 wpm to over 100 wpm and copy was fine at each standard speed. Then I decided to design and build a solid-state motor drive to replace the governor, permitting me to control speed from a console knob.

### speed sensor

The first problem was to sense motor speed. For this I made a pulse wheel about 1-3/4 inch (4.5 cm) in diameter from 0.032-inch (0.8-mm) aluminum sheet (**fig. 1**) and, after removing the governor mechanism, fastened it to the motor shaft. The motor shaft had a hole which accepted a small machine-screw tap, allowing me to bolt the pulse wheel directly to the end of the shaft. A General Electric H13A1 optical coupler completed the motor-speed sensor. The coupler, which consists of a light-emitting diode (emitter) and phototransistor (detector) with a gap between them, mounted in a plastic housing, is designed for pulse-wheel operation. The emitter is excited continuously and the pulse wheel teeth interrupt the beam to the detector, as shown in **fig. 1**. I used a 33-tooth wheel with slots made by sawing 1/4-inch

**RTTY speed control system mounted on a Kleinschmidt page printer showing one-knob speed control, front, and motor-mounted pulse tachometer, rear.**

(6.4-mm) radial cuts with a coping saw. Fortunately, the wheel slots need not be made with precision.

## circuit

The circuit is shown schematically in **fig. 2**. Pulses from the tachometer, squared up by transistor Q1, trigger a monostable multivibrator consisting of Q2 and Q3. The monostable multivibrator converts the tachometer output signal to a series of constant-amplitude, constant-width pulses with repetition rate proportional to motor speed. The average voltage resulting from this pulse train is also proportional to motor speed and so can serve as a highly accurate dc tachometer.

Operational amplifier U1 forms a three-pole Butterworth active filter which develops the required dc voltage from the pulse train. This filter configuration was chosen to give good ripple suppression with minimum time delay. Positive dc output current from U1, proportional to motor speed, is compared to a negative reference current derived from the speed switch and adjusting pots. Op-amp U2 switches sharply from *on* (positive output) to *off* (negative output) when the tach-derived current exceeds the reference current. It serves as a highly sensitive speed detector and drives another optical coupler, this time an H15A1. This coupler is similar to the H13A1 but without the mechanical gap so sensitivity is much higher. The coupler switches transistor Q4 in the gate circuit of the triac which, at long last, turns the motor *on* and *off*. This second optical coupler isolates the control circuit from the 120-volt line.

Operation of the triac circuit is directly analogous to that of the governor. The motor voltage is either *on* or *off*, not continuously phase modulated. This permits considerable simplification in the gating circuitry and provides all the sensitivity needed for this type of application. The cycling rate is somewhat slower than that of the governor, however, probably due to the minimum *on* time limitations of a triac on a 60-Hz line. After working with the control circuitry for a while, you cannot help but admire the simple, rugged and sensitive mechanical governor with which these machines were originally equipped.

The resistors and pots in the speed reference network permit the circuit to

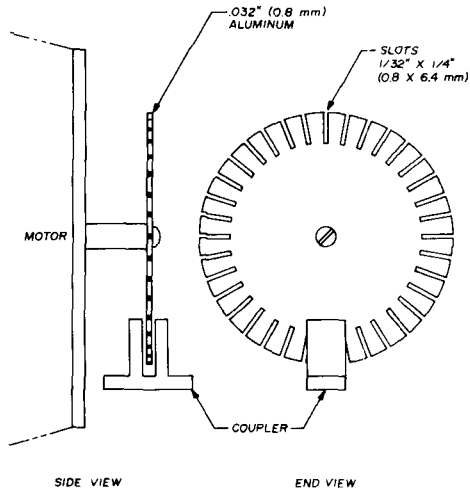



**fig. 1. Plan view of the pulse tachometer. The author used a 33-slot wheel for his Kleinschmidt page printer, but suggests 60 slots if this controller is to be used with a Teletype Corporation machine.**

be adjusted to each of the standard speeds of 60, 67, 75 and 100 wpm; these correspond to baud rates of 45.45, 50.00, 56.88 and 74.20.[1] Baud rates determine the precise speed ratios required, so a frequency counter can be used to set the speeds. In the Kleinschmidt machine, the motor shaft revolves at 3600 rpm for operation at the wpm speeds marked on the gears. Speeds may also be set by trial and error copy and that is how I did the job.

Operation over the range from 60 to 100 wpm is possible with the 100 wpm gears installed. However, the speed stability at 60 wpm leaves something to be desired. I ended up using the 67 wpm gearing and running the motor up to 5400 rpm for 100 wpm copy. This seems

to pose no particular problem for the motor since it will run much faster at full voltage, even under full load. I doubt that the additional bearing or brush wear is significant in amateur service. The 67 wpm gearing results in nearly normal shaft speed (roughly 3240 rpm) at 60

trigger pulses at the base of Q2. With the 15k feedback resistor in place, the monostable pulses at the collector of Q3 must not overlap at the maximum pulse-wheel speed. This may be checked with a scope or by observing the dc voltage at the collector of Q2.

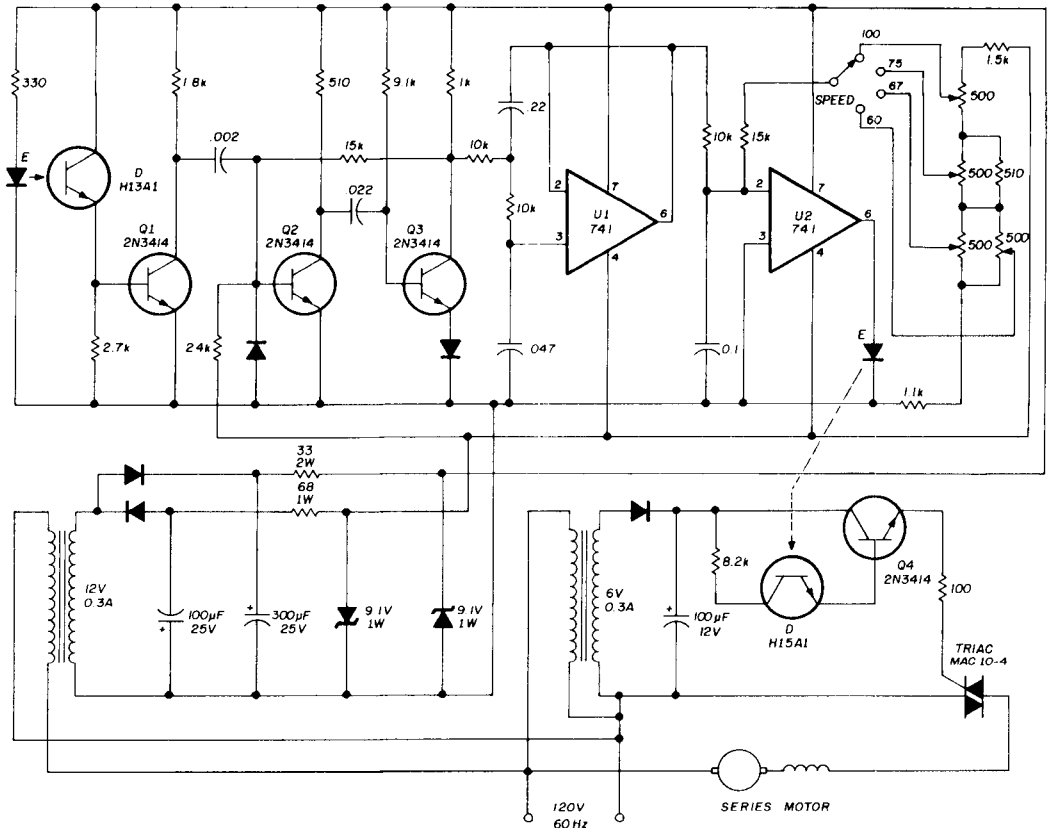



**fig. 2. Schematic diagram of the RTTY speed-control circuit. Watch for built-in hash-suppression capacitors in the printer motor circuit, as they can destroy the triac motor driver.**

wpm, and motor momentum serves to smooth out speed fluctuations caused by the rapidly clutched load.

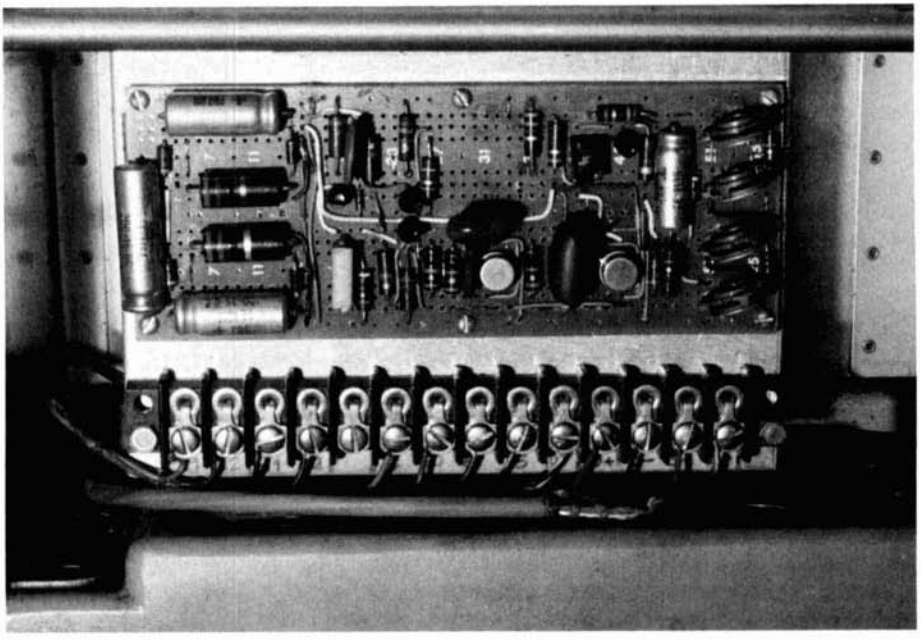
## adjustment

Some comments on adjustments are in order since no two pulse wheels or photo couplers will be identical. The 330-ohm LED dropping resistor and the 2.7k resistor in the base of Q1 may be changed, if necessary, to produce clean, steady

The voltage should be proportional to pulse-wheel speed over the desired speed range, reaching about 3 volts at maximum speed. Decreasing the 0.022-μF timing capacitor or decreasing the 9.1k timing resistor will narrow the pulses and reduce the average voltage. The best combination is the one which permits the maximum voltage while maintaining linearity to 100 wpm.

The range on the speed pots is deliber-

ately restricted to make adjustment easier. The values shown, together with the 1.1k resistor to ground, allow exact speed *ratios* to be set. Exact speed *settings*, however, may require changing the 1.5k upper divider resistor or the 15k op-amp input resistor to compensate for amperes. Higher current triacs or better heat sinking would permit the use of this speed control circuit with larger motors. Remember that the triac must supply 5 to 10 times normal current at turn-on while the motor is at zero speed. Also, a larger triac may require additional gate



**Circuitry for the RTTY speed control system is mounted on small perforated board which is installed on the rear of the page printer.**

zener diode tolerances, resistor tolerances or gearing different from that described.

One precaution should be observed regarding the triac: Do not connect a capacitor, even a small one, directly across the triac or load. The surge current at turn-on can instantly destroy the triac. A resistor of at least 22 ohms should be inserted in series with any capacitor which may already be present or which you may wish to add for noise suppression. My unit caused some receiver hash while on the bench, but quieted down completely when installed in the machine and connected to the built-in rf filter. The MAC10-4 triac, mounted to the chassis with the insulating hardware supplied, should handle loads to at least 3 drive and a boost in the gate power supply.

## circuit components

None of the components used in this circuit are critical, though the timing resistor and capacitor should be types that are stable. Metal-film resistors and polycarbonate or polystyrene capacitors are suitable. If the GE photocoupler is not readily available, you can build your own using separate LEDs and phototransistors. Nearly any type of npn transistor is suitable for Q1 through Q4 (I used 2N3414s). The same is true for the diodes. Signal-type silicon diodes should be used in the transistor circuits, and lead-mount power diodes of at least

50-volt PIV in the power supplies. The op-amps may be individual 741 units or the 747 dual 741/741; pin numbers are shown for the TO5 type 741. Surplus units are available at attractive prices from various suppliers. The 6- and 12-volt power transformers are available from Radio Shack for about $1.50. Cost of the parts should not exceed $25, even if most are bought new.

I am not yet an expert on the Teletype Corporation machines except to note that the older ones, at least through the Model 26, have 1800 rpm synchronous motors. Teletype governor motors are in the same general speed range. This would suggest the use of a pulse wheel with at least 60 slots in order to get the tach frequency up near the design value. With that one change, the control unit described here should be suitable for Teletype machines with series governor type motors. It is *not* recommended for synchronous motors. Replacement series motors are available from advertisers in *RTTY Journal* and *ham radio* for about $15.00.

In summary, my variable-speed Kleinschmidt machine has now been on the air for several months. Those patient hams who have coped with my typing have reported no speed problems, and the copy has been excellent on my end. Commercial stations have been copied at all four speeds with perfect results as far as speed is concerned. Reworking surplus machines and building controls of this sort may be viewed by some as an unrewarding chore, but the pleasure of achieving instant speed change by twisting a little knob made it all worthwhile for me. Now for that FRXD20 in the corner . . .

**Author W3VF using the variable-speed Kleinschmidt RTTY machine at his station in Pennsylvania.**

**reference**

1. "Principles of Telegraphy—Teletypewriter," NAVSHIPS 0967-255-0010.

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The DKB-2010 is equally versatile in the CW mode, with complete alphanumeric and punctuation keys, speeds from 8-60 WPM, and a "DE-call sign" key. The DKB-2010 includes a three-character buffer operational in either the RTTY or CW mode. Optional 64 or 128 key buffer also available.

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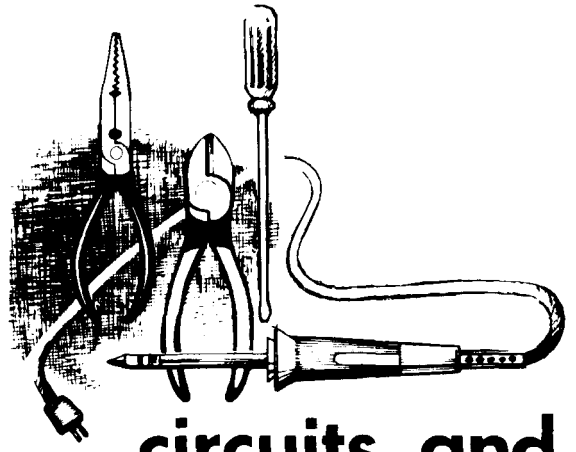


# circuits and techniques

ed noll, W3FQJ

## battery power

**Amateur radio is entering** a new era of battery operations. Battery-powered, hand-held and portable fm transceivers are just one example. Battery-powered QRP operation is also popular. Look for a new emphasis on battery operation during field-day activities. In fact, the very changeover from vacuum tube to all solid-state electronic gear has awakened new interest in battery applications.

The energy crisis is the catalyst for further expansion. The battery-powered bus has made a successful debut; the battery-powered family run-about waits behind the oil curtain. However, the real expansion is likely to be within the framework of solar power. Batteries will carry us through the night.

The all solar-powered ham station is no wild fantasy. The primary-cell battery is a one-shot affair. A typical example is the common zinc-carbon battery. After its chemical energy has been converted to electrical energy it is discarded. The secondary-cell battery is rechargeable. Its energy can be drained off and then resupplied by recharging the battery from a source of electrical power such as a solar-energy converter or a standard battery charger. The most well-known secondary battery is the lead-acid battery used in your automobile.

When your battery-powered ham gear is removed from your car, the two most common secondary batteries are the nickel-cadmium and dry gelatin-electrolyte, lead-acid types.

### battery ratings

Be it a primary or secondary type, the two most common battery ratings are voltage and ampere-hours (or milliampere-hours). Voltage is no problem because there are a wide variety of types available according to voltage. There are many 12-volt types, matching the most common voltage requirement of solid-state radio gear. Other voltages can be obtained with the proper series-parallel groupings of standard-voltage batteries. The parallel connection, of course, increases current capability and available ampere-hours.

The ampere-hour or milliampere-hour ratings of batteries are usually based on 10 or 20 hours of continuous operation. For example, a popular 12-volt nickel-cadmium battery has a 1.2 ampere-hour rating. This is based on a 10-hour discharge time and a cut-off voltage of 11 volts. What continuous current demand could be made on the battery over this

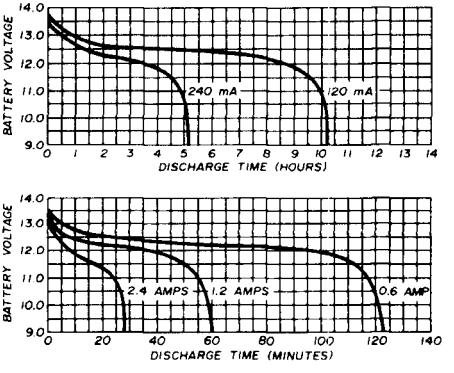



**fig. 1. Discharge characteristics of a typical nickel-cadmium secondary battery (courtesy Eveready).**

10-hour period? Since the ampere-hour rating of the battery and operating time are known,

$$I = \frac{\text{Ampere-hour rating}}{\text{Time}} = \frac{1.2}{10}$$

$$= 120 \text{ milliamperes}$$

The ampere-hour rating is less when there is a greater current demand and is likely to be more for a lesser current demand. Graphs and charts are available for various commercial batteries and from these you can determine primary battery life or when a secondary battery needs to be recharged. A typical graph is shown in **fig. 1.**

The upper curve shows the 120- and 240-milliampere discharge curves. Notice, on the 120-mA curve, that at the end of 10 hours the battery's voltage has declined to 11 volts. If the current demand is doubled to 240 mA, the 11-volt level is reached after something less than 5 hours, indicating that the ampere-hour capacity of the battery is somewhat less than its 1.2 rating for a 10-hour period. The bottom set of curves shows the discharge time in minutes when a high current demand is made on the battery. Note that, for a current demand of 1.2 amperes, the 11-volt level is reached after a time interval of 55 minutes.

An example of a battery chart is given in **table 1** for the popular D-size zinc-carbon (LeClanche) dry battery. Battery life is related to how many hours per day it is switched into operation. Take a current drain of 100 mA as an example. Note that, for 2-hours operation per day, the battery potential will drop to 1.2 volts after 29 hours. When the battery is operated continuously with a current drain of 100 mA its anticipated life to cutoff potential of 1.2 volts is only 9.6 hours.

**table 1. Hours of life chart for Eveready 950 D-cell.**

| schedule | starting drains (mA) | cutoff voltage 0.8V | 0.9V | 1.0V | 1.1V | 1.2V |
|---|---|---|---|---|---|---|
| 2 hours/day | 10 | 525 | 500 | 475 | 450 | 430 |
| | 20 | 295 | 270 | 260 | 240 | 210 |
| | 30 | 210 | 185 | 175 | 155 | 135 |
| | 50 | 125 | 113 | 103 | 89 | 77 |
| | 100 | 57 | 50 | 45 | 35 | 29 |
| | 150 | 33 | 29 | 25 | 18.5 | 14 |
| | 200 | 21.5 | 18 | 15.5 | 11.5 | 8 |
| | 250 | 15 | 12 | 10 | 7.2 | 4.5 |
| | 300 | 11 | 8.5 | 7 | 5 | 2 |
| 4 hours/day | 10 | 660 | 620 | 580 | 530 | 470 |
| | 20 | 330 | 310 | 290 | 260 | 230 |
| | 30 | 220 | 200 | 185 | 155 | 125 |
| | 50 | 123 | 108 | 96 | 81 | 64 |
| | 100 | 50 | 41 | 36 | 30 | 22 |
| | 200 | 18 | 13.5 | 12 | 9 | 5.2 |
| | 300 | 8 | 6 | 3.5 | 3 | 2 |
| 8 hours/day | 10 | 700 | 660 | 620 | 560 | 460 |
| | 20 | 340 | 310 | 270 | 230 | 180 |
| | 30 | 210 | 180 | 150 | 130 | 100 |
| | 50 | 105 | 82 | 70 | 60 | 50 |
| | 100 | 39 | 28 | 23 | 18 | 13.5 |
| 24 hours/day | 10 | 1050 | 745 | 600 | 500 | 370 |
| | 20 | 360 | 260 | 210 | 165 | 125 |
| | 30 | 200 | 145 | 115 | 88 | 65 |
| | 50 | 92 | 67 | 52 | 40 | 29 |
| | 100 | 32 | 24 | 18.5 | 13.5 | 9.6 |
| | 200 | 11.5 | 8.5 | 6.4 | 4.5 | 3.2 |
| | 300 | 6 | 4.5 | 3.5 | 3 | 2 |

The 1.5-volt LeClanche dry cells have been more or less standardized as to physical size and capacity. The data of **table 2** are typical. Ratings are based on an operating temperature of 70°F, two operating hours per day and a cut-off voltage of 1 volt for the first ten cells listed and 0.8 volt for the remaining cells except numbers 176 and 335, which are based on a cut-off of 1 volt.

**table 2. Operating-hour capacities of standard Leclanche dry cells (courtesy Eveready).**

| cell | starting drain (mA) | service capacity (hours) | cell | starting drain (mA) | service capacity (hours) | cell | starting drain (mA) | service capacity (hours) |
|---|---|---|---|---|---|---|---|---|
| | 1.5 | 275 | | 0.4 | 210 | | 2 | 190 |
| N | 7.5 | 52 | 105 | 2 | 30 | 143 | 10 | 40 |
| | 15 | 24 | | 4 | 8 | | 20 | 15 |
| | 2 | 290 | | 0.5 | 435 | | 2 | 510 |
| AAA | 10 | 45 | 108 | 2.5 | 103 | 145 | 10 | 105 |
| | 20 | 17 | | 5 | 51 | | 20 | 43 |
| | 3 | 350 | | 0.6 | 710 | | 2 | 560 |
| AA | 15 | 40 | 109 | 3 | 155 | 146 | 10 | 115 |
| | 30 | 15 | | 6 | 75 | | 20 | 50 |
| | 5 | 420 | | 0.7 | 210 | | 2 | 610 |
| B | 25 | 62 | 112 | 3.5 | 35 | 148 | 10 | 130 |
| | 50 | 25 | | 7 | 12 | | 20 | 70 |
| | 5 | 430 | | 0.7 | 300 | | 3 | 550 |
| C | 25 | 100 | 114 | 3.5 | 57 | 162 | 15 | 150 |
| | 50 | 40 | | 7 | 25 | | 30 | 65 |
| | 10 | 500 | | 0.8 | 475 | | 3 | 600 |
| D | 50 | 105 | 116 | 4 | 98 | 163 | 15 | 165 |
| | 100 | 45 | | 8 | 49 | | 30 | 72 |
| | 15 | 400 | | 1 | 500 | | 3 | 770 |
| E | 75 | 70 | 125 | 5 | 105 | 165 | 15 | 200 |
| | 150 | 30 | | 10 | 45 | | 30 | 90 |
| | 15 | 520 | | 1 | 475 | | 5 | 780 |
| F | 75 | 105 | 127 | 5 | 150 | 172 | 25 | 200 |
| | 150 | 45 | | 10 | 72 | | 50 | 90 |
| | 15 | 1000 | | 1.3 | 275 | | 5 | 1000 |
| G | 75 | 150 | 132 | 6.5 | 40 | 175 | 25 | 260 |
| | 150 | 65 | | 13 | 16 | | 50 | 110 |
| | 50 | 700 | | 1.3 | 450 | | 10 | 910 |
| 6 | 250 | 150 | 133 | 6.5 | 80 | 176 | 50 | 165 |
| | 500 | 70 | | 13 | 35 | | 100 | 63 |
| | 0.4 | 200 | | 1.3 | 450 | | 3 | 370 |
| 104 | 2 | 28 | 135 | 6.5 | 108 | 208-1 | 15 | 75 |
| | 4 | 7 | | 13 | 52 | | 30 | 35 |
| | 3 | 550 | | 5 | 1000 | | 10 | 1900 |
| 213-1 | 15 | 110 | 240-5 | 25 | 430 | 260-6 | 50 | 445 |
| | 30 | 50 | | 50 | 180 | | 100 | 210 |
| | 5 | 630 | | 5 | 1800 | | 10 | 375 |
| 240-2 | 25 | 270 | 250-5 | 25 | 750 | 335 | 50 | 78 |
| | 50 | 110 | | 50 | 375 | | 100 | 37 |

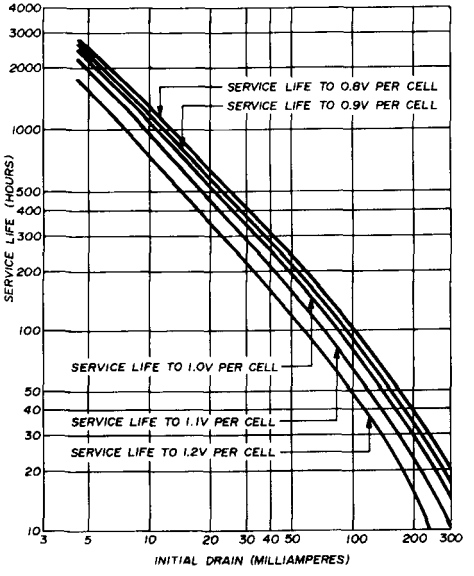
Use a D-size cell as an example. If a current drain of 100 mA for two hours per day is assumed, the service life will be 45 hours. This can be verified from the specific chart for a D-cell given in **table 1**. These basic cells are used to construct many of the higher voltage and higher current LeClanche dry-cell batteries. The F-type cell, for example, is popular in the construction of several popular communications batteries. To determine the service life when cells are connected

in parallel you need only divide the current drain by the number of parallel cells. Of course, the number of cells connected in series determines the final voltage and equals the number of cells times the voltage per cell.

A chart such as that shown in **fig. 2** gives more detail on the capacity of an individual cell type. In this example, service life in hours is plotted against current demand for various values of cut-off voltage.

What would be the service life in hours to a cut-off of 1.2 volts with a 50 mA current drain? From the 1.2-volt curve in **fig. 2** this can be determined as 120 hours. Figures are based on four hours of operation per day (this could be typical for many of the more active radio amateurs).

What would happen to the service life if two of these cells were connected in parallel, placing a current demand of only 25 mA on each cell? The 25 mA line in **fig. 2** intersects the 1.2-volt curve at approximately 270 hours. Note that this more than doubles the service life expected from a single cell.




**2. Estimated service life for F-type batteries when discharged 4 hours per day at 70°F (courtesy Burgess Battery).**

Temperature has a decided influence on battery discharge. In the D-type carbon-zinc cell example of **fig. 3** the decline to 1 volt occurs in about 1 hour at 70°F while the drop to 1-volt occurs at

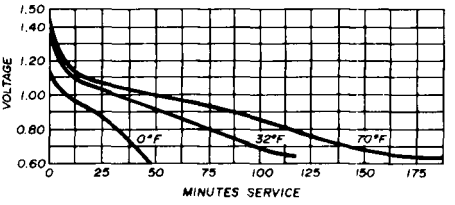



**fig. 3. Temperature influence on rate of battery discharge (courtesy Eveready).**

32°F in only one-half hour. Figures assume a current demand of 667 mA.

## basic battery types

In experimenting with solid-state circuits and in QRPP operations of 1 watt and under, I usually use the common lantern battery. The 12-volt Eveready 732 and Burgess Radar-Lite TW2 consist of eight F-type dry cells in series. The data of **fig. 2** are appropriate.

A current drain of 100 mA corresponds to an available power of 1.2 watts. If the lantern battery were subject to four hours of continuous operation per day the individual cell voltage would fall to 1.2 volts after 50 hours of operation.

This seems to be a short time. However, a number of additional factors must be considered. Do you operate four hours per day? How many hours per day would the 1.2-watt demand be made on the battery? This is important when you consider that your receive time is always longer than your transmit time. You do a substantial amount of listening around the band and then, depending upon whom you are in contact with, the transmit and receive times can be estimated at 50%. Furthermore, in CW operation you are placing an intermittent demand on the battery rather than asking for a continuous 1 watt of power. It may well be that during a 4-hour operating period your key may be *down* for one

hour or less. Thus, your actual battery life may be 4 to perhaps as high as 6 times greater than is suggested by the 50-hour life figure. This represents 200 to 300 hours of operating time and, in terms of the usual ham QRPP activity, you are talking about months of operation.

Two lantern batteries in parallel more than double the operating time. Or you can step up to the Eveready Hot-Shot 1463. This battery uses 16 G-type cells, **table 2**, connected in two parallel strings of eight. Since there are two sets in parallel, you must either halve the current values given under *starting drain* or double the *service capacity hours*, to obtain an approximate service capacity figure of the G-type battery data of **table 2**. This actual figure will be somewhat greater than the chart indicates because, as pointed out, the service capacity more than doubles when current drain is halved.

A rechargeable battery designed specifically for electrical and electronic applications is the alkaline-manganese dioxide type shown in **fig. 4**. Although rechargeable, their electrochemical systems can be hermetically sealed. Such batteries are

**fig. 4. Rechargeable alkaline-manganese battery type 564 (courtesy Eveready).**

maintenance free and they operate in any mounting position. Electrodes are made of zinc and manganese dioxide while the electrolyte is potassium hydroxide.

These cells come in two forms, meeting the physical dimensions of the D- and G-type dry cells. The characteristics of the Eveready D and G cells are given in **table 3**. Note the voltage values and the high ampere-hour capacities of these cells.

Higher voltage and/or higher discharge current capacities are obtained by using these fundamental cells in series and parallel groupings. This 564 battery, shown in **fig. 4**, uses nine G cells in series and has a 5 ampere-hour capacity that can deliver 1.25 amperes for a period of four hours without recharge. We are now talking about more than 10 watts of available power and, in fact, 10 watts continuous for a period of four hours. As mentioned previously, four hours of continuous key-down operation usually corresponds to more than 12 hours of continuous operating time.

Of course, you can anticipate many days of operation without a recharge. Considering that the battery can be recharged 25 or more times, there is adequate energy available to last a year or more for even the most active 5- to 10-watt QRP operator.

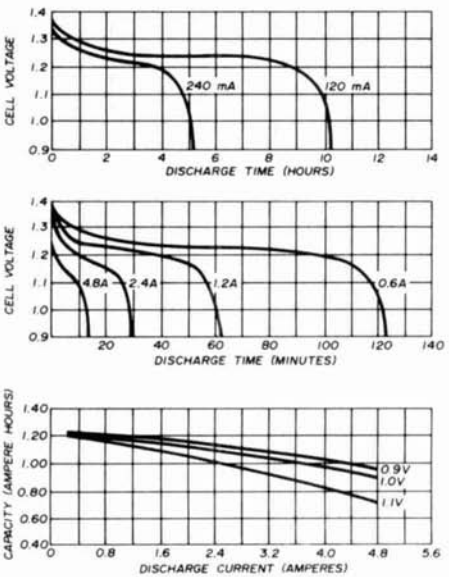



**fig. 5. Characteristics of a nickel-cadmium cell (courtesy Eveready).**

fig. 6. Sealed six-volt nickel-cadmium battery (courtesy Eveready).

The rechargeable nickel-cadmium battery is a popular secondary battery for use in electronics and electrical systems. Again, it is a shielded battery and there are no corrosive fumes or the need for adding electrolyte. An especially attractive advantage of the nickel-cadmium battery is its nearly constant discharge potential. The discharge-charge cycle may be repeated as many as 300 to 500 times.

table 3. Characteristics of basic alkaline-manganese cells.

| cell size | nominal voltage | average operating voltage | rated ampere-hour capacity | maximum recommended discharge current |
|---|---|---|---|---|
| D | 1.5 | 1.0 - 1.2 | 2.5 | 0.625 ampere |
| G | 1.5 | 1.0 - 1.2 | 5.0 | 1.25 ampere |

This means that a nickel-cadmium battery selected for most amateur applications will have an exceedingly long life it if is not abused.

Eveready nickel-cadmium 1.25-volt cells are available in button (20-300 milliampere-hours), cylindrical (150-4000 mA-hours), and rectangular (6-23 ampere-hours) types. Individual cells are welded together to obtain higher operating voltages. The cell voltage-discharge time characteristics of a typical cell are given in **fig. 5**. Note that the voltage on discharge holds rather constant over the discharge time until near the break in the curve. It is not advisable to let the cell voltage drop below 1.1 volt before recharge is initiated. In so doing the cell voltage is held up and the life of the battery is extended. The lowest graph shows the capacity-discharge current characteristic of the cell. For example, it shows that with a 1.2-ampere discharge current and a cutoff of 1.1 volt, the battery has an ampere-hour capacity of about 1.12 ampere-hours.

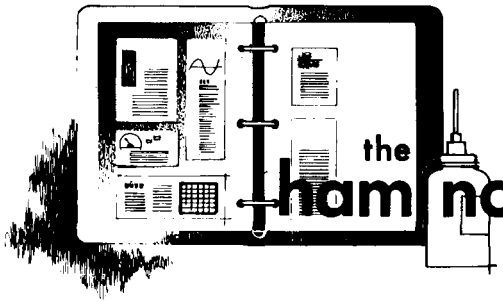
The Eveready N86 battery consists of ten of these cells connected in series to obtain 12.5 volts. On the basis of a 10-hour discharge at a rate of 120 mA, the capacity of the battery is 1.2 ampere-hours. Its discharge characteristic is shown in **fig. 1**. Note that the battery voltage drops to 11 volts near the 10-hour calibration line when the current demand is 120 mA.

There are many nickel-cadmium battery types. The Eveready 1007, **fig. 6**, is a four ampere-hour, six-volt battery that is completely encased. On a 10-hour basis it would have a rated current of 400 mA. It includes a socket for plugging in a companion charger. The Burgess CD33 is a 6-volter of lantern-battery size with a 2 ampere-hour capacity and includes a built-in charger.

The nickel-cadmium battery can be trickle-charged and kept up to full charge just as you would maintain an ordinary lead-acid storage battery. Usually the trickle-charge current is about one-quarter of the rated discharge current.

Next month's column covers battery chargers and the increasingly popular gelatin electrolyte lead-acid secondary battery. I will also discuss how a solar power converter can be used to trickle-charge or fully charge the various types of rechargeable batteries.

**ham radio**



# the ham notebook

## temporary fix for noisy volume controls

Gain control pots eventually become intermittent at the point of maximum use and thus can make a fine piece of equipment almost unusable. This happened to the audio gain control in my Collins 51J3, and having torn the receiver apart once before to work on the PTO I had no desire to go through all that work again just to change a noisy potentiometer.

Since a worn pot manifests itself by sudden jumps in level, distortion and bursts of noise, I reasoned that a "fix" that had a stabilizing effect at the tube grid might suppress the problem sufficiently to make the receiver usable again. Many audio circuits resemble the Collins circuit shown in **fig. 1**, so my first attempt was to put a fixed resistor from the wiper (tube grid) to ground. This did exactly what I wanted, and after a little experimentation to find optimum value (5k still provided enough audio to drive me from the room, yet reduced the effect of the noisy spot to the point where I have to listen carefully to find it) my faithful 51J3 was back in business.

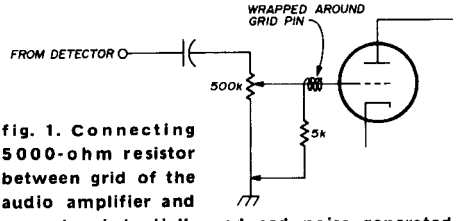



**fig. 1. Connecting 5000-ohm resistor between grid of the audio amplifier and ground substantially reduced noise generated by worn 500k volume control.**

Being essentially lazy, and seeing that this was a "temporary" repair anyway, I didn't even pull the receiver out of the cabinet to add the resistor. Instead, I simply wrapped a piece of wire around the grid pin of the audio tube, ran the wire up alongside the tube and out through the top of the shield, and soldered the 5k resistor to it. The other end of the resistor is grounded by a handy nearby wing nut. It may not look very nice, but it sure works well— and someday, when I *really* have to tear into the receiver, I *do* plan to replace that noisy pot!

**Joe Schroeder, W9JUV**

## counted frequencies

In some configurations, a frequency counter may not properly show the received (or transmitted) frequency. I refer to those cases where a *clarifier* or variable bfo may be used. For example, in the Collins 75S-3 receiver the variable bfo changes the beat-note on CW. However, the 32S-3 exciter in transceive continues to use its own crystal bfo. Thus, a receiver frequency counter may not correctly show the transmitted frequency nor the frequency to which the receiver is tuned.

Similar peculiarities can occur in the use of the clarifier, a term used in Yaesu and some other designs. The nature of these devices should be studied before a counter frequency is relied upon to show the frequency that you are interested in.

**Bill Conklin, K6KA**

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# new products

## two-meter fm sets

General Aviation Electronics (Genave) has introduced a new vhf fm system called *Mobiline*. This system, which consists of *Mobiline I* and *II* two-way fm mobile units and a variety of fixed base stations, offers considerable system flexibility. *Mobiline I*, for example, is designed for use in lightly populated areas with low signal density communications environments. These units accommodate two communications channels in the frequency range from 143.9 to 173.4 MHz, and are equipped with separate volume and squelch controls and transmit indicator light. A plug-in microphone and mobile mounting bracket with anti-theft device are included at no extra charge.

The *Mobiline II* provides the same basic capability as the *Mobiline I*, but has additional circuitry to permit use in heavily populated, high signal density communications environments. Refinements in the receiver section provide higher selectivity, improved spurious response and superior adjacent channel rejection. The *Mobiline II* like *Mobiline I*, features nominal 25-watts output power and 0.5 $\mu$V sensitivity for 20 dB quieting.

Either of these two radios is easily adaptable to fixed based station use. The Genave base-station packages include a stainless-steel 3-dB gain antenna with 50-feet of RG-8/U coaxial cable and connectors. Also included is the standard hand microphone (optional desk-type microphones are available starting at $34.95). Another important option is the *MobilPack* portability accessory. This allows the *Mobiline* owner to operate portable in the field or in vehicles without electrical systems. The *MobilPack* will provide a minimum of 24 hours of service on full charge and costs $124.95. Also available for the Genave *Mobiline* system is a sub-audible tone squelch system called *MobilGuard*.

The *Mobiline I* is priced at $319.95, the *Mobiline II* is $399.95 (including one channel). For more information write to General Aviation Electronics, 4141 Kingman Drive, Indianapolis, Indiana 46226, or use *check-off* on page 94.

## test equipment for the radio amateur

Techniques of measurement and instrumentation have progressed rapidly in recent years, with the result that many very sophisticated methods of measurement are now available to the serious radio amateur. The development of modern semiconductor devices has meant that many items of equipment that were previously barred from the amateur workshop on the grounds of complexity, cost or size, have suddenly become a realistic possibility.

This new book by H.L. Gibson, G8CGA, published by the RSGB, explains in detail the theory behind modern measurement techniques, and goes on to describe many items of equipment of special interest to the amateur experimenter and home builder. Many of the construction articles feature instruments that have not before appeared in



More Details? CHECK–OFF Page 94

print. Readers are taken through the basics of indicating and electronic instruments, and on to the techniques of frequency, power and noise measurement using up-to-the-minute components and methods. Included are chapters on meters, electronic instruments, dip oscillators, frequency and rf power measurements, noise measurement, antenna and transmission-line measurements, signal sources and attenuators, oscilloscopes, swept-frequency measurements, and components, vacuum tubes and transistors.

The section on electronic instruments includes circuit details on vacuum-tube voltmeters, fet voltmeters, transistor multimeters, diode probes and input attenuators. The chapter on dip oscillators includes valuable information on using the instrument as well as construction details for several solid-state units. The frequency measurement chapter covers frequency standards, crystal calibrators, digital counters, absorption wavemeters, harmonic indicators and a simple audio-frequency meter.

The chapter on rf power measurements includes data on dummy loads, thermal converters, rf ammeters, rf voltmeters, thermistor/bolometer bridges and directional wattmeters. Noise sources, noise generators, noise factor comparators and routine noise-figure checks are discussed in the chapter on noise, and vswr meters, vhf/uhf reflectometers, field strength meters and noise bridges are covered in the chapter on antenna measurements. Also described in the book are a rf signal generator, an audio signal generator, a two-tone test oscillator, oscilloscopes, modulation monitors, i-f sweep generators, an RCL bridge, a capacitance meter, a logic tester, a fet mutual conductance tester and many others. The reference data section includes much useful electronic and mechanical data as well as instructions for temperature and air-flow measurements. Hardbound, 132 pages. $5.95 from Ham Radio Books, Greenville, New Hampshire 03048.


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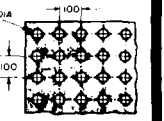


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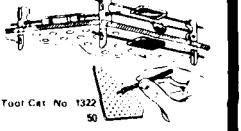

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The second instrument is called the model 310A and adds variable pulse to the basic functions of the model 300A. The 310A's TTL compatible pulse can be varied from 1-μs to 10-millisecond pulse width and has rise and fall times better than 25 nanoseconds. All the standard 300A features are included.

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Tucker Electronics Company is best known as the world's largest distributor of reconditioned test instruments with an inventory exceeding 15,000 instruments. Tucker currently sells no less than 18 lines of new instruments including Weston Instruments, T.R.I. Corporation, Philips and several other well known lines.

For more information, write to Tucker Electronics Company, Post Office Box 1050, Garland, Texas 75040, or use *check-off* on page 94.



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239 Rt. 46, Saddle Brook, N. J. 07662
Phone: (201) 489-9000

# TS-520

## Kenwood's new go every place... do everything transceiver.

**The TS-520 is the transceiver you have always wanted, but could not buy until now. It is a no compromise 5 band unit for both SSB and CW that performs equally well whether it is at home, in your car, airplane, boat or trailer.**

**The TS-520 features both a built-in AC power supply and a 12 volt DC power supply plus a built in VOX with adjustable gain, delay and antivox for complete flexibility.**

**See Electronics Center for your new Kenwood TS-520. You'll be glad you did.**

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Electronics Center carries complete lines of Ham equipment, accessories and antennas. Write or call Walt, W5ZYA, or Al, W5PXH for your HAM needs.

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| PRICES | | POST PAID |
|---|---|---|
| TC 2 | — | $7.00 |
| TC 3 | — | $7.50 |
| Spinner (-S) | — | $1.00 |

Add $0.75 for Air or UPS

**Case:** 2x4"; shaft ¼"x3"
**Model TC2:** Skirt 2⅛"; Knob 1⅝"
**Model TC3:** Skirt 3"; Knob 2⅜"

**R. H. BAUMAN SALES**
P.O. Box 122, Itasca, Ill. 60143

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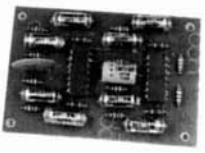
## CW FILTER



**New Model CWF-2BX—$19.95.** Ready to use. Please include $1.00 postage.

**Model CWF-2—$12.95, Kit.** $14.95 Wired, tested, guaranteed. Please include 55c postage.

- **Get Razor Sharp selectivity from any receiver or transceiver.**
- **Extremely high skirt rejection.**
- **Drastically reduces all background noise.**
- **No audible ringing.**
- **No impedance matching.**
- **Ultra modern active filter design uses IC's for super high performance.**

We have what we think is the finest CW filter available anywhere. The 80 Hz selectivity with its steep sided skirts will allow you to pick out one signal and eliminate all other QRM and QRN. Simply plug it into the phone jack or connect it to the speaker terminals of any receiver or transceiver and use headphones, small speaker, or speaker amplifier. Better yet, connect it between any audio stages to take advantage of the built in receiver audio amplifier.

Build the 2"x3" CWF-2 PC card into your receiver or get the self contained and ready to use CWF-2BX and plug in!

**SPECIFICATIONS**

BANDWIDTH: 80 Hz, 110 Hz, 180 Hz (Switch selectable)
SKIRT REJECTION: At least 60 db down 1 octave from center frequency for 80 Hz bandwidth
CENTER FREQUENCY: 750 Hz
INSERTION LOSS: None. Typical gain 1.2 at 180 Hz BW, 1.5 at 110 Hz BW, 2.4 at 80 Hz BW
INDIVIDUAL STAGE Q: 4 (minimizes ringing)
IMPEDANCE LEVELS: No impedance matching required
POWER REQUIRED: CWF-2: 6 volts (2 ma.) to 30 volts (8 ma.); CWF-2BX: standard 9 volt transistor radio battery
DIMENSIONS: CWF-2: 2"x3" PC board; CWF-2BX: 4"x3 1/4"x2 3/16" (black wrinkle steel top, white aluminum bottom, rubber feet)

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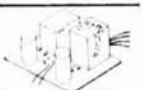

**UNUSED PRINTED CIRCUIT BOARD ASSEMBLY.** Manufacturers overrun. His loss your gain.

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Price: $3.25 ea. ppd.

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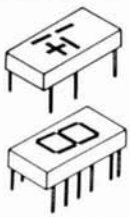

Use Standard 7447 Decoder-driver. Seven Segment Readouts. All tested and guaranteed. Specs included. Fit standard 14 pin DIP socket. Full .335 inch high. Color, RED

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| Less Decimal | $2.00 ppd. |
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Same unit only contains numeral 1 and plus and minus sign. $2.25 ppd.

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JUST ARRIVED — Transformer, 115 VAC primary, 18 volt, 5 amp ccs or 7 amp intermittent duty secondary $6.00 ea. ppd.

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Transformer — American Made — Fully shielded. 115 V Primary. Sec. — 24-0-24 @ 1 amp with tap at 6.3 volt for pilot light.
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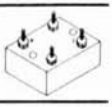

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**NEW NEW NEW NEW**

Factory New Semtech Bridge Rectifiers
ALL 10 AMPS

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| 50 Volt PIV | $1.75 ea. |
| 100 Volt PIV | $2.00 ea. |
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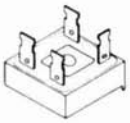
| 400 Volt PIV | $2.50 ea. |

All Postpaid USA



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- **AMERICAN MADE!!**
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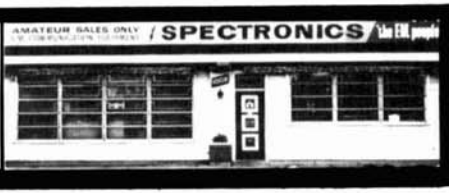


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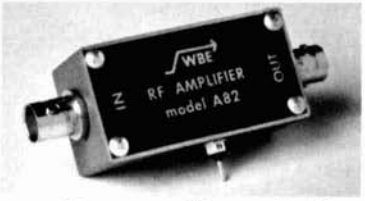


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(see QST Review, May 1973, pg. 41)

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All prices include U.S.A. shipping. Add $5 for air shipment. Ill. res. add 5% sales tax.


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PREAMPLIFIER

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*WA4ILS* (Hugh) Says "Couldn't have made weak station contacts without it."

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Note: Above evaluations on Collins 75A4, S-Line, Drake R4-B, R4-C Signal-One, FPM 300

### Specifications

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- Ultra Low Noise-High *Useful* Gain
- Gain: 20 db min. Typical 25 db
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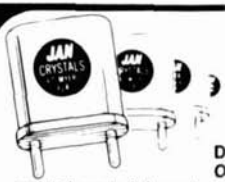

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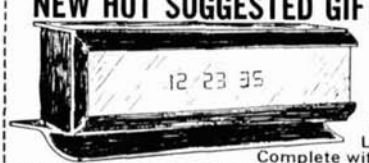


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| ☐ SN7471 | .55 |
| ☐ SN7472 | .50 |
| ☐ SN7473 | .55 |
| ☐ SN7474 | .55 |
| ☐ SN7475 | 1.00 |
| ☐ SN7476 | .65 |
| ☐ SN7478 | .95 |
| ☐ SN7480 | .65 |
| ☐ SN7481 | 1.25 |
| ☐ SN7482 | .99 |
| ☐ SN7483 | 1.25 |
| ☐ SN7486 | .55 |
| ☐ SN7489 | 3.50 |
| ☐ SN7490 | 1.49 |
| ☐ SN7491 | 1.35 |
| ☐ SN7492 | 1.35 |
| ☐ SN7493 | 1.35 |
| ☐ SN7494 | 1.35 |
| ☐ SN7495 | 1.35 |
| ☐ SN7496 | 1.35 |
| ☐ SN74100 | 1.65 |
| ☐ SN74107 | .70 |
| ☐ SN74108 | .95 |
| ☐ SN74112 | .95 |
| ☐ SN74113 | .95 |
| ☐ SN74114 | .95 |
| ☐ SN74121 | .60 |
| ☐ SN74122 | .95 |
| ☐ SN74123 | 1.20 |
| ☐ SN74125 | .71 |
| ☐ SN74126 | .71 |
| ☐ SN74140 | 1.25 |
| ☐ SN74141 | 1.95 |
| ☐ SN74145 | 1.85 |
| ☐ SN74148 | 4.50 |
| ☐ SN74150 | 1.61 |
| ☐ SN74151 | 1.25 |
| ☐ SN74153 | 1.60 |
| ☐ SN74154 | 2.10 |
| ☐ SN74155 | 1.55 |
| ☐ SN74156 | 1.45 |
| ☐ SN74157 | 1.55 |
| ☐ SN74158 | 1.55 |
| ☐ SN74160 | 1.95 |
| ☐ SN74161 | 1.75 |
| ☐ SN74163 | 1.95 |
| ☐ SN74164 | 2.95 |
| ☐ SN74165 | 2.10 |
| ☐ SN74166 | 2.08 |
| ☐ SN74173 | 2.50 |
| ☐ SN74175 | 3.20 |
| ☐ SN74176 | 2.10 |
| ☐ SN74177 | 2.10 |
| ☐ SN74180 | 1.20 |
| ☐ SN74181 | 3.95 |
| ☐ SN74182 | 1.20 |
| ☐ SN74185 | 2.50 |
| ☐ SN74192 | 1.95 |
| ☐ SN74193 | 1.95 |
| ☐ SN74194 | 1.95 |
| ☐ SN74195 | 1.25 |
| ☐ SN74196 | 2.50 |
| ☐ SN74197 | 1.50 |
| ☐ SN74198 | 2.65 |
| ☐ SN74200 | 9.95 |

● "DIP" Packages

## 7-SEGMENT LED Readouts

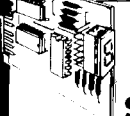
### (All "LED" TYPES)

| Type | Char. | Each | Special |
|---|---|---|---|
| ☐ MAN-1 | .27 | $3.75 | 3 for $9. |
| ☐ MAN-3 | .12 | 1.49 | 3 for $3. |
| ☐ MAN-4 | .19 | 2.50 | 3 for $6. |

### REFLECTIVE BAR TYPES

| | | | |
|---|---|---|---|
| ☐ 707* | .33 | 2.50 | 3 for $6. |
| ☐ 704* | .33 | 2.50 | 3 for $6. |
| ☐ SLA-1** | .33 | 2.10 | 3 for $5. |
| ☐ SLA-3** | .70 | 4.95 | 3 for $13 |
| ☐ SLA-11** | .33† | 3.50 | 3 for $10 |
| ☐ SLA-21** | .33†† | 3.95 | 3 for $10. |

*By Litronix. **By Opcoa, equal to MAN-1 or MAN-4 specs. Color - RED. †Green, †† yellow



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| READOUT | Char. | Maker |
|---|---|---|
| ☐ MAN-1 | .27 h. | Monsanto |
| ☐ MAN-4 | .19 h. | Monsanto |
| ☐ 707* | .33 h. | Litronics |
| ☐ 704** | .33 h. | Litronics |
| ☐ SLA-1* | .33 h. | Opcoa |

* Pin-for-pin MAN-1, ** Pin-for-pin MAN-4, elec. char. same

**METAL-ENCASED**

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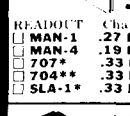
**6.3 VOLT 3 AMP**

Heavy-duty, 110VAC to at 3 amps filament transformer. 3 x 2⅛ x 2¼. With color-coded wires.




## SANKEN HYBRID AUDIO POWER AMPS

| | M'fgr's Type | Watts | Sale |
|---|---|---|---|
| ☐ | SI-1010Y | 10 | $ 8.88 |
| ☐ | SI-1025E | 25 | 18.88 |
| ☐ | SI-1050E | 50 | 29.95 |

Used extensively in hi-fi systems, tape decks, FM tuners, record players, stereo components, musical instruments, P.A., etc. All amplifiers, flat within ½ db from hz to 100,000. Each unit properly heat-sinked, with heavy-duty connecting tie lug connections. Single-ended pushpull output. Power supply required 21VDC. Output to 8 ohms. Order by Stock No.

### SILICON TUBES

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|---|---|
| ☐ 5U4 | $1.49 |
| ☐ 5R4 | 3.95 |
| ☐ 866 | 7.95 |

### HIGH VOLT 1AMP

| PIV | SALE |
|---|---|
| ☐ 2000* | 1.00 |
| ☐ 3000 | 1.35 |
| ☐ 4000 | 1.65 |
| ☐ 5000 | 2.25 |
| ☐ 6000 | 2.96 |
| ☐ 8000 | 3.50 |
| ☐ 10000 | 3.95 |

### EPOXY FULL WAVE SILICON BRIDGE RECTIFIERS

Code: 2 amp TO-5 case

| PIV | 2 Amp | 6 Amp |
|---|---|---|
| 50 | ☐ $.69 | ☐ $.88 |
| 100 | ☐ .79 | ☐ .99 |
| 200 | ☐ .95 | ☐ 1.25 |
| 400 | ☐ 1.19 | ☐ 1.50 |
| 600 | ☐ 1.35 | ☐ 1.75 |
| 800 | ☐ 1.59 | ☐ 1.95 |
| 1000 | ☐ 1.79 | ☐ 2.25 |

6 Amp ½ x ½ x 1/16 sq

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10-Amp Power Tab Plastic Units

| PRV | Sale |
|---|---|
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| ☐ 100 | .95 |
| ☐ 200 | 1.25 |
| ☐ 300 | 1.50 |
| ☐ 400 | 1.98 |
| ☐ 500 | 2.25 |
| ☐ 600 | 2.50 |

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More Details? CHECK–OFF Page 94

# flea market

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■ **COPY** No special layout or arrangements available. Material should be typewritten or clearly printed and must include full name and address. We reserve the right to reject unsuitable copy. **Ham Radio** *can not check out each advertiser and thus cannot be held responsible for* claims made. Liability for correctness of material limited to corrected ad in next available issue. Deadline is 15th of second preceding month.

■ **SEND MATERIAL TO:** Flea Market, Ham Radio, Greenville, N. H. 03048.

**RESISTORS:** Carbon composition brand new. All standard values stocked. ½W 10% 40/$1.00; ¼W 10% 30/$1.00 — 10 resistors per value, please. Minimum order $5.00. 15W RMS IC Audio Amplifier — Panasonic. Frequency response 20Hz-100 kHz. ½% distortion. Price $6.95 Postpaid. Pace Electronic Products, Box 161-H, Ontario Center, New York 14520.

**WORLD QSL** — See ad on page 92.

**COLLECT WORLD STAMPS** *commemorating* telecommunications topics. 25¢ brings mint selections on approval plus booklet "Collect Topicals and Have Fun". Alkanstamps, Box 3494, Scottsdale, AZ 85257.

**MODEL 15 & 19 RTTY.** Large quantity of surplus Teletype gear and accessories available from WB5CBC. Must be picked up in Las Cruces, N. M., no shipping. Details for SASE from WB5CBC or Box RTTY, Ham Radio, Greenville, NH 03048.

**WARREN HAMFEST,** largest family style hamfest in East. Sunday, August 18th, at famous Yankee Lake Park. Giant fleamarket, swimming, picnicking — All Free. QSL W8VTD, Box 809, Warren, Ohio 44482.

**HAMFAIR** - 74 August 17th & 18th, Pierce City Fairgrounds, Graham, Wash. The outstanding hamfest in the Northwest this year. Technical seminars, contests, displays & prizes. Flea market, free camping, Saturday night dinner. Details from Bill Morgan, W7GPR, 3421 E. 138th St., Tacoma, Washington 98446.

**WANTED:** ARC-51, 618T-1, ARC-102, FM-633, ARC-131, 807A Wilcox, Transceivers. Pay Cash. Bob Sanett, 616 S. Holmby Ave., Los Angeles, CA. (213) 279-1275.

**TELETYPEWRITERS** — Kleinschmidt — portable, fixed, sets, punches, parts, reconditioned, reasonable. Mark/Space Systems, 3563 *Conquista, Long* Beach, Calif. 90808. 213-429-5821.

**FOR THE PROMOTION OF** International Radio Scouting, an attempt is being made to locate boy, girl, and adult scouters that hold amateur radio licenses. Could scouting amateurs supply me with their name, address, amateur call, class of license, scouting position, etc. Don Wibel K9ECE/WI9BSA, 5115 Delaware Ave., Fort Wayne, Indiana 46805.

**THE 9TH ANNUAL MELBOURNE HAMFEST** is September 7-8. Air conditioned, $1.50, tables $2/day. PCARS, P. O. Box 1004, Melbourne, FL 32901.

**STOLEN** on or about May 22, 1974: Swan 400 transceiver with #406VFO, 117X AC Power Supply and D104 microphone. Eico #720 CW Transmitter, Eico #722 V.F.O., Heathkit HR-20 Receiver, Globe Scout CW Transmitter, Hallicrafters SX99 Receiver, MC-4 Mobile Console Wattmeter, Homebrew Transmatch, CD Ham M Station Console. If you have any information please contact WA2HGG or Hall of Science Radio Club, Box 1032, Flushing, N. Y. 11352.

**RTTY EQUIPMENT FOR SALE** including machines, parts, gears. Send us a list of your teletype needs. Atlantic Surplus Sales, 1902 Mermaid Ave., Brooklyn, N. Y. 11224.

***THE NORTH TEXAS REPEATER ASSOCIATION*** *invites* all amateurs to attend the Texas VHF-FM Society Convention Friday evening, Saturday and Sunday, August 2, 3 and 4 at the Dallas West Ramada Inn in Irving Texas. Activities will include displays, technical sessions, prizes and the feature speaker, A. Prose Walker, W4BW, of the FCC. Tickets $3 for *pre-registration*, $4 at the door. Drawing for those that pre-register. Checks may be made to the Texas VHF-FM Society Convention. For information write Texas VHF-FM Society, P. O. Box 3823, Irving, Texas 75061.

**FIGHT TVI** with the RSO Low Pass Filter. For brochure write: Taylor Communications Manufacturing Company, Box 126, Agincourt, Ontario, Canada. MIS 3B4.

**THE CENTRAL MISSOURI AMATEUR RADIO CLUB,** Sedalia, Missouri, and The Warrensburg Amateur Radio Club, Warrensburg, Missouri, will sponsor a club station at the Missouri State Fairgrounds, Sedalia, Missouri, August 16th through August 25th. This event has been awarded the special call WMØSF.

***HOMEBREWERS:*** *Stamp brings* list of high quality components. CPO Surplus, Box 189, Braintree, Mass. 02184.

**HYDROPONICS** for XYL while QRL. Build-yourself garden components, books, nutrients. 5 page catalog, send 40¢; refundable. Incorporated 3-1971. BURWELL GEOPONICS, Box 125-DB, Rancho Sanfe, CA 92067.

**WANTED.** Instruction manual for APR-4 receiver and vhf/uhf tuning units. Will return after I make a copy. Jim Fisk, editor-in-chief, Ham Radio, Greenville, NH 03048.

**SWAN** 350 with 117-C, clean, $295. You ship. K1YLV, 203-272-4417.

**QSL'S — BROWNIE W3CJI** — 3035B Lehigh, Allentown, Pa. 18103. Samples with cut catalog 35¢.

**WANTED: HAM RADIO** January, March, April and July 1969, need to complete personal collection. KH6FMT, P. O. Box 758, Koloa Kauai, HI 96756. 808-742-2002.

**DO-IT-URSELF DXPEDITION** — Stay at ZF1SB — Caymen Is. Vertical antenna and Caribbean at your doorstep. Diving/fishing if band folds. Write Spanish Bay Reef Resort, Box 800K, Grand Cayman, B. W. I.

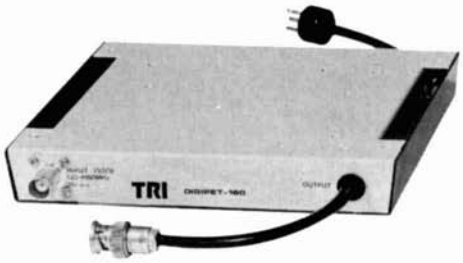
**SARA HAMFEST.** Sunday, August 11, 1974, Riverside Park, Murphysboro, Illinois. Tickets $1.00, 3 for $2.00. Write Wm. Johnson, 502 W. Kenicott, Carbondale, Ill. 62901.

**MIX PLEASURE WITH PLEASURE** at the Hamburg International Hamfest near Niagara Falls on September 21. For information contact Lin Brownell WB2HCL, 210 Buffalo, Hamburg, N. Y. 14075.

**TELL YOUR FRIENDS about Ham Radio Magazine.**

# OUR DIGIPET 60 IS A GENERAL-PURPOSE FREQUENCY COUNTER WITH A RATING OF 1 kHz TO 60 MHz.

# (PLUS 130 MHz TO 160 MHz)




Perfectly designed for the radio amateur who wants quality, accuracy *and* economy.

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Write *immediately* for more information.

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**BUY—SELL—TRADE.** Write for monthly mailer. Give name, address, call letters. Complete stock of major brands new and reconditioned equipment. Call us for best deals. We buy Collins, Drake, Swan, etc. SSB & FM. Associated Radio, 8012 Conser, Overland Park, KS. 66204. 913-381-5901.

**SIGNAL ONE OWNERS,** expert and prompt service by ex-Signal/One engineer. Also will purchase your functioning or not functioning unit or spare parts. Write or call for details. Larry Pace, K2IXP/7, 5717 Genematas, Tucson, AZ. 85704 (602-888-5234).

**WANTED:** Excellent 2 meter amp. mod. transceiver. Benson, 7554 Trask Ave., Playa del Rey, Calif. 90291. (213) 823-1860. Local only.

**WANTED - USED FM** 2-way radio communications equipment and test equipment. Mot., GE and RCA etc. No doggies please, CAL-COM Systems, Inc., 701-51A Kings Row, San Jose, Calif. 95112, Tel. 408/998-4444.

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**VHF-UHF PRE-AMPS.** 432 MHz receive and transmit converters. Send for illustrated information. Carmichael Communications, P. O. Box 256, Carmichael, CA. 95608.

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**RTTY'ERS ADD PERF TAPE** to your rig. Friden 2115 tape punch, 2314 Electrodata reader, and selecta data reader. $150.00. Will work on 5, 7, and 8 channel tape. Ted Dum, 11852 Davenport Road, Los Alamitos, California 90720, 213-431-1852.

**WANT OLD RADIO SHOW TRANSCRIPTION** discs. Any size or speed. Send details to, Larry Kiner, W7FIZ, 7554 132nd Ave N.E., Kirkland, Wa. 98033.

**THE 26TH ANNUAL** South Jersey Radio Association Hamfest, Sunday, Sept. 8, 1974, at 10 A.M., rain or shine, at Molia Farms Picnic Grounds (intersection of Routes 42 and 47). Swap shops (tail-gate and table-top), electronic equipment displays, prizes, ladies' games, and grab bags for the children. Picnic tables are available; in addition, hamburgers, hot dogs, corn and soft drinks may be purchased. Free parking. Talk in on 145.2 and 3.930 MHz. Advance registration $2; $3 at the gate. Write to Bill Brandberg, W2BBN, 322 Lakeview Ave., Haddonfield, N. J. 08033.

**TELETYPEWRITER PARTS,** gears, manuals, supplies, tape, toroids. SASE list. Typetronics, Box 8873, Ft. Lauderdale, Fl. 33310. Buy parts, late machines.

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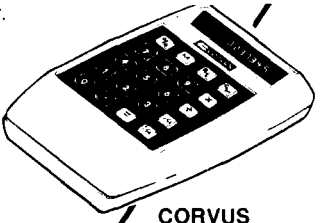

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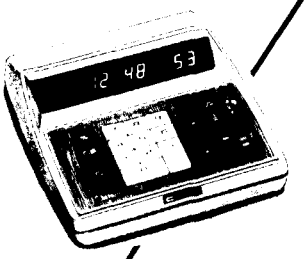

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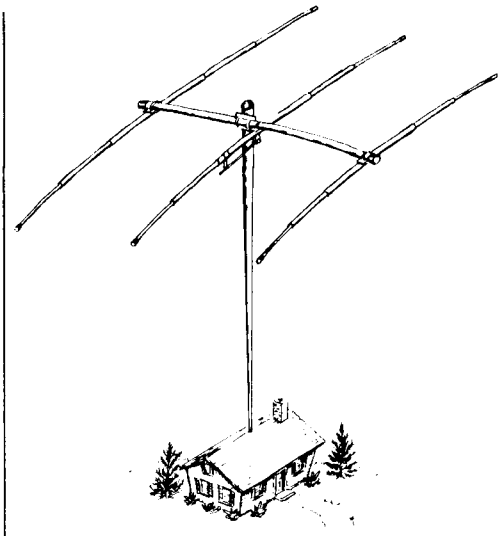

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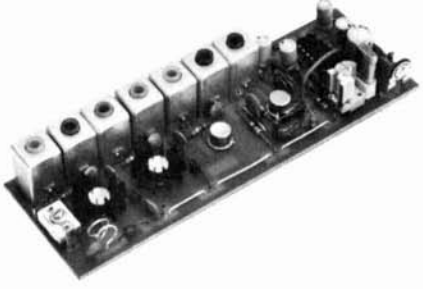

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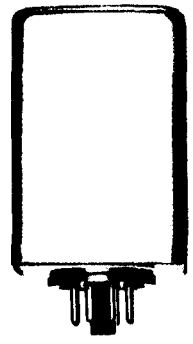

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| Boonton 202D (sim. to above) 175-250 MHz | 225 |
| HP100D-Freq, stand. w/scope-Acc. 1ppm | 85 |
| HP185A Scope w/186B amp sampling 1gHz | 335 |
| HP202A Function Gen. .008-1200Hz | 95 |
| HP205AG Audio Gen .02-20kHz-metered | 195 |
| HP330B Dist anal 20 Hz-20kHz .1% | 205 |
| HP524D-Freq Counter. Basic unit 10Hz-10MHz | 185 |
| HP540B Trans osc. for 524 to 12.4gHz | 185 |
| HP608D (TS510A/U) sig. gen. 10-420MHz | 450 |
| HP610B Sig Gen .45-1.2gHz calib attn | 365 |
| HP803A Imp Bridge 50-500MHz, 2-200 ohm | 195 |
| Panoramic SPA-4 Spec. Anal. Bandswitching, 10MHz-44gHz, 5 or 70MHz sweep width | 985 |
| Polarad MSG34-Sig. Gen 4.2-11gHz calib attn. AM-FM-Pulse mod. | 495 |
| Polarad R uwave rcvr .4-84gHz with plug-in AM, FM, CW, Pulse - less plug-in | 225 |
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| Stoddart NM10A (URM-6) RF intens mtr 10-250 kHz, complete with acc. | 630 |
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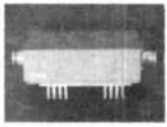

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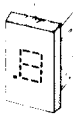
## MAN 1



7-Segment, 0-9 plus letters. Snaps in 14-pin DIP socket or Molex. Operates with IC voltage requirements. Long operating life.
ONLY $3.25

| | | | |
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| 7401 | .20 | 7453 | .20 |
| 74H01 | .35 | 7454 | .25 |
| 7402 | .35 | 74L54 | .35 |
| 7403 | .30 | 74L55 | .35 |
| 7404 | .28 | 7460 | .20 |
| 74H04 | .35 | 74L71 | .30 |
| 7405 | .28 | 7472 | .40 |
| 7406 | .70 | 74L72 | .50 |
| 7408 | .35 | 7473 | .60 |
| 74H08 | .35 | 74L73 | .75 |
| 7410 | .25 | 7474 | .65 |
| 74H11 | .35 | 74H74 | .80 |
| 7413 | 1.25 | 7475 | 1.40 |
| 7417 | .40 | 7476 | .60 |
| 7420 | .25 | 74L78 | .80 |
| 74L20 | .35 | 7480 | .65 |
| 74H20 | .35 | 7483 | 1.00 |
| 74H22 | .35 | 7489 | 4.00 |
| 7430 | .25 | 7490 | 1.20 |
| 74H30 | .35 | 7492 | .90 |
| 74L30 | .40 | 7493 | 1.15 |
| 7440 | .25 | 7495 | 1.15 |
| 74H40 | .35 | 74L95 | 2.00 |
| 7441 | 1.25 | 74107 | .70 |
| 7442 | 1.20 | 74121 | 1.25 |
| 7446 | 1.75 | 74154 | 2.30 |
| 7447 | 1.50 | 74193 | 1.50 |
| 7448 | 1.50 | 74195 | 1.00 |
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| 74H50 | .35 | | |
| 7451 | .25 | | |

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| V5647 | 2A | 600V | 1.10 |
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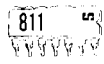


## MAN 3

0-9 plus letters. Right-hand decimal point. Flat-pack type case. Long operating life. IC voltage requirements. Ideal for pocket calculators!

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## MAN4

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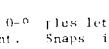

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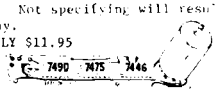
This kit provides a highly sophisticated display section module for clocks, counters, or other numerical display needs. The unit is .8" wide and 4 5/8" long. A single 5-volt power source powers both the ICs and the display tube. It can attain typical count rates of up to 30 MHz and also has a lamp test, causing all 7 segments to light. Kit includes a 2-sided (with plated thru holes) fiberglass printed circuit board, a 7490, a 7475, a 7447, a DR 2016 RCA Numitron display tube, complete instructions, and enough Molex pins for the ICs . . NOTE: boards can be supplied in a single panel of up to 10 digits (with all interconnects); therefore, when ordering, please specify whether you want them in single panels or in one multiple digit board. Not specifying will result in shipping delay.

COMPLETE KIT, ONLY $11.95
FULLY-ASSEMBLED UNIT $15.00




Boards supplied separately @ $2.50 per digit.

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Atlas ___ 198
Babylon ___ 014
Barry* ___
Bauman ___ 017
Budwig ___ 233
CFP ___ 022
Caddell ___ 244
Communications Unltd ___ 248
Comtec ___ 151
Cush Craft ___ 035
Delavan ___ 235
Drake ___ 039
ECM ___ 190
Ehrhorn ___ 042
Eimac ___ 043
Electronics Center ___ 236
Epsilon ___ 046
Erickson ___ 047
Expo '74 ___ 147
General Aviation ___ 168
Gray ___ 055
Greene's ___ 253
Gregory* ___
Hal ___ 057
Hal-Tronix ___ 254
Ham Radio ___ 150
Hamtronics ___ 246
Henry ___ 062
House Dipoles ___ 036
Icom ___ 065
International Crystal ___ 099
International Field Day* ___
Jan ___ 067
Janel ___ 068
K. E. ___ 072
Leland ___ 193
Logic ___ 133
MFJ ___ 082
Martex ___ 197
Matric ___ 084
McClaren ___ 155
Midland ___ 086
Nasem ___ 249
Nurmi ___ 090
Palomar ___ 093
Poly Paks ___ 096
Prof. Elect. ___ 140
RMS ___ 239
Callbook ___ 100
Raytheon ___ 101
Regency ___ 102
Robot ___ 103
SAROC ___ 146
Space-Military ___ 107
Specialty ___ 216
Spectronics FM ___ 191
Spectrum ___ 108
Swan ___ 111
Symtek ___ 203
T. R. I. Corp. ___ 225
Tech. Doc. ___ 226
Tekpro ___ 250
Tri-Ex ___ 116
Tri-Tek ___ 117
Tucker ___ 113
VHF Eng. ___ 121
Webster ___ 255
Weinschenker ___ 122
Wide Band Eng. ___ 256
Wilson ___ 123
Wolf ___ 124
World QSL ___ 125
Yaesu ___ 127

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# Advertisers Index


ATV Research ... 68
Amtech ... 75
Atlas Electronics ... 63

Babylon Electronics ... 93
Barry ... 96
Bauman ... 68
Budwig Manufacturing Co. ... 80

CFP Enterprises ... 78
Caddell Coil Corp. ... 69
Communications Unlimited ... 73
Comtec ... 69
Cush Craft ... 39, 89

Delavan Electronics, Inc. ... 72
Drake, Co. R. L. ... 43

ECM Corporation ... 78
Ehrhorn Technological Operations, Inc. ... 1
Eimac, Div. of Varian Assoc. ... Cover IV
Electronics Center, Inc. ... 68
Epsilon Records ... 92
Erickson Communications ... 67, 86
Expo '74 ... 70

Gray Electronics ... 91
Greene's Electronics ... 69
Gregory Electronics ... 67

Hal Communications Corp. ... 55, 75
Hal-Tronix ... 80
Ham Radio ... 48, 49, 67
Hamtronics, Inc. ... 69
Henry Radio Stores ... Cover III
House of Dipoles ... 92

Icom ... 77
International Crystal Mfg. Co. Inc. ... 74
International Field Day ... 67

Jan Crystals ... 80
Janel Labs ... 68

K. E. Electronics ... 75

Leland Associates ... 69
Logic Newsletter ... 72

MFJ Enterprises ... 68
Martex Corporation ... 78
Matric ... 92
McClaren ... 76
Midland Electronics Company ... 80

Nasem ... 76
Nurmi Electronic Supply ... 65

Palomar Engineers ... 91
Poly Paks ... 82
Professional Electronics ... 75

RMS Corporation ... 80
Radio Amateur Callbook ... 87, 92
Raytheon Company ... 2
Regency Electronics, Inc. ... 85
Robot Research ... 81

SAROC ... 67
Space-Military Electronics ... 92
Specialty Products ... 72
Spectronics FM ... 71
Spectrum International ... 78
Swan Electronics ... Cover II
Symtek, Inc. ... 76

T. R. I. Corporation ... 84
Technical Documentation ... 66
Tekpro Design Systems ... 92
Tri-Ex Tower Corp. ... 5
Tri-Tek, Inc. ... 67
Tucker Electronics ... 88

VHF Engineering, Div. of Brownian Elect. Corp. ... 90

Webster Radio ... 75
Weinschenker, M. ... 69
Wide Band Engineering Co. Inc. ... 72
Wilson Electronics ... 79
Wolf, S. ... 76
World QSL Bureau ... 92

Yaesu Musen USA ... 95

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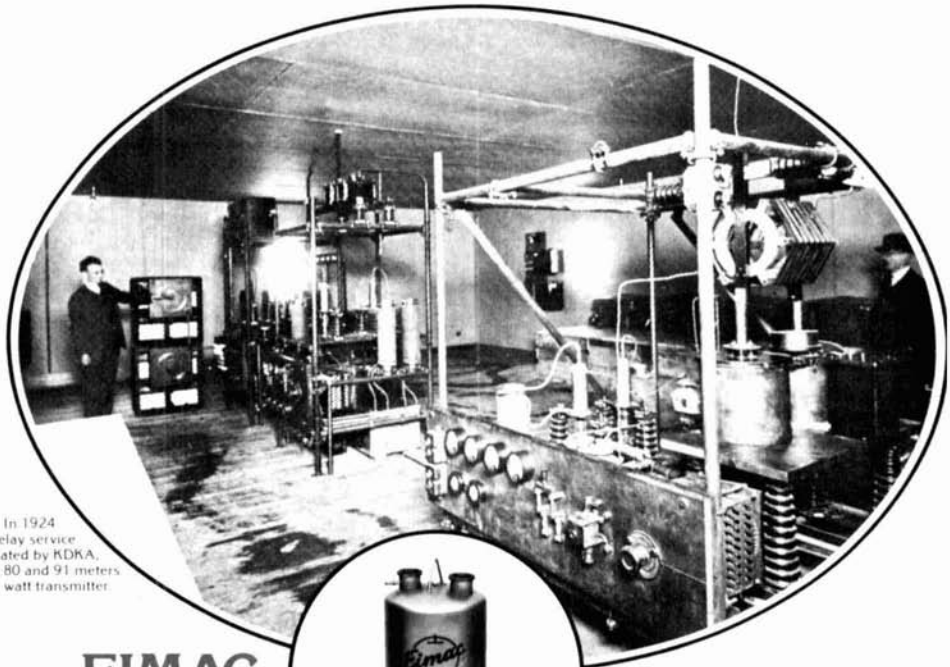

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